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PETROLEUM GEOLOGISTS

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MARCH—APRIL, 1922

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CONTENTS

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MARCH—APRIL, 1922

OIL POSSIBILITIES OF WESTERN KANSAS

By Charles T. Lupton, Wallace Lee and L. R. Van Burgh

GENERAL STATEMENT

The area described in this report lies in the Great Plains Region of Western Kansas and embraces parts of six counties, namely, Scott, Lane, Ness, Logan, Gove and Trego. The greater part of the area lies between the Union Pacific and Missouri Pacific Railways.

Part of the area along Smoky Hill River was examined in the spring of 1920 and the greater part was examined during the winter of 1920-21, most of the work being done along the valley of Smoky Hill River in Gove and Logan counties.

SURFACE FEATURES

The topography of the region is in general that of the Great Plains, flat, treeless, undulating prairie at an elevation of about 3300 feet, cut by streams whose valleys are 200 to 300 feet lower, frequently being steep sided and abrupt and often having rim rocks of Tertiary conglomerate.

GEOLOGY

STRATIGRAPHY

The surface rocks of much of the Great Plains area are Tertiary, Quaternary and Recent deposits and alluvium, but the underlying Cretaceous rocks are usually exposed along the deeper stream valleys and their tributaries. In most of the

area examined rocks of Niobrara age are present, together with some Pierre in scattered localities. Below the Cretaceous are the Kiowa shale and the Cheyenne sandstone of Comanchean age, and beneath these are the Permian and Pennsylvanian which form the surface rocks of the eastern part of the state.

Tertiary

The Tertiary consists chiefly of conglomerate, calcareous sand, gravel and clay, with some impure limestone. These beds were deposited unconformably on the weathered and eroded post-Cretaceous surface. The relief of this surface was probably not less than 1500 feet and, while not having steep and abrupt slopes, it was probably more intricately dissected than the present surface. The approximate contact of the Tertiary with older deposits is shown by Darton[1].

Cretaceous

Pierre—The Pierre is the highest formation of the Cretaceous exposed, and is brought down in a synclinal area in the western part of T. 15 S., R. 32 W. It consists of the usual type of dark and blackish shales. It frequently weathers to a yellowish gray and outcrops exhibit abundant selenite crystals. No fossils were observed. Very few outcrops of Pierre occur in the area.

Niobrara—With the exception of the above mentioned scattered outcrops of Pierre, the Niobrara is the only Cretaceous formation exposed. It consists almost entirely of chalk and contains numerous thin shell beds of *Ostrea congesta,* particularly in the middle part, and thin marcasite bands and nodules. Thin and very localized lignite seams are sometimes found. The color varies from creamy white to yellow, buff and blue. It contains no definite datum planes, although certain zones are distinguishable. A rough classification of horizons may be based upon certain physical characteristics but there is no sharp line of demarcation between the divisions. The formation contains abundant *Ostrea* and huge *Inocerami* and fossil remains of vertebrates.

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[1]Darton, N. H. The Structure of Parts of the Central Great Plains: U. S. Geol. Survey. Bull. 691A, Plate 1, 1918.

The following section measured in Sec. 17, T. 15 S., R. 32 W., shows the variations in the upper 300 feet.

Section of Niobrara beds measured in Sec. 17, T. 15, R. 32 W.

Pierre shale.
Niobrara chalk

5.	Chalk, bluish and buff, feebly bedded, with *Ostrea* and other fossils	18 ft.
4.	Yellow, buff chalk, distinctly bedded, no *Ostrea*. When fresh has deep blue color	100 ft.
3.	Blue *Ostrea*-bearing chalk with faint lamination, not bedded. Locally carries coarse *Ostrea* 1 inch in diameter	32 ft.
2.	Soft, white, faintly laminated chalk, *Ostrea* not abundant though occasionally present but not in sheets. Practically free from fossils and ironstone bands	33 ft.
1.	Blue slaty chalk with ironstone bands and sheeted aggregations of *Ostrea*	117 ft.
	Total	300 ft.

Bed 4 is the most striking horizon and can usually be recognized by the color, but where unweathered and fresh can be distinguished by the slightly darker, bluish color and the distinctive bedding. Bed 2 is often not strikingly distinguished but Bed 1 is definitely characterized by the presence of well marked, weathered, ferruginous bands, sheeted aggregations of *Ostrea* and an abundance of huge thin shelled *Inocerami*.

Lower in the section and lower in the valley of the Smoky Hill these beds are succeeded by white and bluish chalk, with a change in the type of *Inocerami*. This is succeeded downward in turn by a zone of alternating bedded blue and white chalk and at the base is the strikingly characteristic Ft. Hays limestone with its well bedded deposits of white chalk, about 70 feet thick.

The Niobrara, being a decidedly brittle member, has practically no capacity for internal adjustment of strains, so that the area is conspicuously affected by minor faulting. Evidences of major faulting of a deep seated character are also present.

The total thickness of the Niobrara is about 700 feet.

Cretaceous Below the Niobrara

No exposures of the Cretaceous below the Niobrara occur in

this area. The following composite section from outcrops farther east is reported by Darton[2].

Composite section of Benton and Dakota formations in western Kansas (after Darton)

Benton formation	
Carlile shale	
Victoria or Blue Hills shale	
Loose dark blue gray shale	100 ft.
Ostrea shale.	
Clay or soft blue gray shale with thin limestone beds	150 ft.
Greenhorn limestone.	
Thin limestones and shale	65 ft.
Graneros shale.	
Bituminous shale	30 ft.
Dakota sandstone	
Brown cross-bedded sandstone and shale	250 ft.

In view of well logs now available in western Kansas the thickness of the Benton which is here reported is too low. Its total thickness is over 400 feet. In a well drilled in Sec. 27, T. 15 S., R. 31 W., by the Plateau Oil Corporation the Benton was found to be 435 feet thick and was composed mostly of loose dark blue, gray and brown shales with 70 feet of limestone.

Dakota At the outcrop the upper part of the Dakota consists of gypsiferous and salty shales, but in the well drilled north of Garden City, in Sec. 35, T. 21 S., R. 31 W., several beds of sandstone 15 to 20 feet thick occur in upper part, which is 100 feet thick in the log. In the sections measured at the outcrop there is frequently found below the upper division a thin bed of çoal or black shale, which seems to be represented in the Garden City log by 10 feet of black shale. The lower part of the Dakota consists of alternating sands and shales aggregating 190 feet in the Garden City log. There were three sands in this part, 13, 58 and 17 feet thick. The total thickness of the Dakota in this well was 321 feet and it contained 7 sands.

In the Plateau well the Dakota was 225 feet thick and consisted of alternating sandstone and shales. Four sands, from 15 to 20 feet in thickness, were present. A well drilled near Utica in Sec. 1,T . 17 S., R. 26 W., showed only 120 feet of Dakota containing two sands, one 10 feet and the other 15 feet thick.

[2]Darton, N. H. Preliminary Report on the Geology and Underground Water Resources of the Central Great Plains; U. S. Geol. Survey. Professional Paper No. 132.

Comanchean

Comanchean beds outcrop only in scattered localities along Medicine Lodge and Cimarron rivers and in McPherson County, the outcrop in all other localities where it might be expected being covered by the overlapping Tertiary. At the

INDEX MAP OF WESTERN KANSAS.

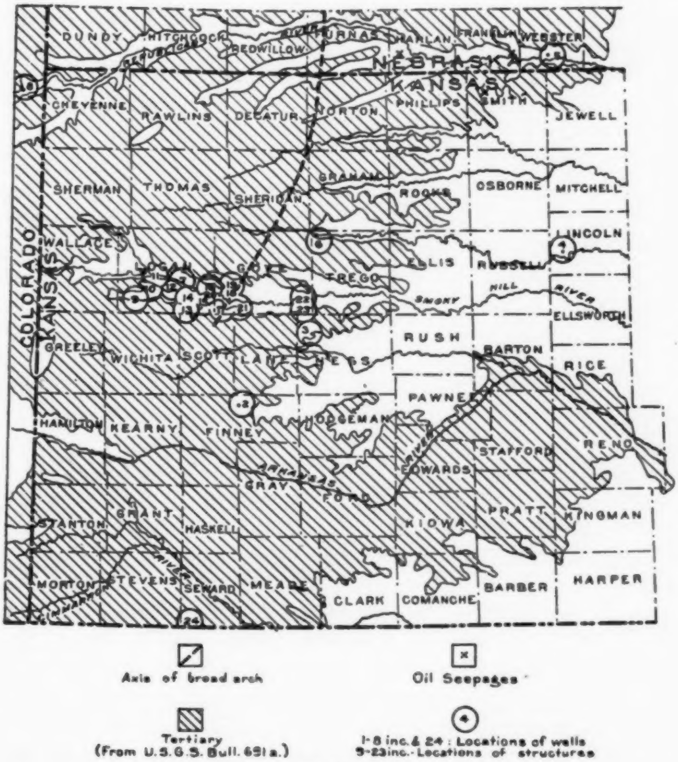


Plate I

outcrop in southwestern Kansas this division consists of a basal sandstone formation 40 to 50 feet thick, called the Cheyenne, and an upper formation consisting of black and dark shale and thin limestones 125 feet or more in thickness, called

the Kiowa. They here have a maximum thickness of 200 feet. The log of the Garden City well showed a thickness of 380 feet, a hitherto unknown thickness for this region. This log showed 5 sands in the Comanchean 7 to 69 feet thick. The Utica log showed 420 feet of Comanchean, and the Plateau log 400 feet.

The Kiowa beds of Western Kansas are northern representatives of the Washita of Texas, the highest division of Comanchean age. In northeastern New Mexico and southeastern Colorado they are found above the Morrison, which is separated from the upper Red Beds by a marked angular unconformity.

In southeastern Colorado the Dakota-Comanche group consists essentially of an upper and lower sandstone, separated by a relatively thin member (20 feet) of shales and clay. The upper member (true Dakota) and the lower member (now known to be of Comanchean age) are usually composed of massive more or less cross-bedded sandstone of about the same thickness, the whole aggregating about 250 feet, though in some localities it is somewhat thicker. It appears that after the pre-Morrison peneplanation in this region an early movement of the Rocky Mountain flexure occurred, carrying a downward fold along an axis paralleling the Rockies in which the fresh water Morrison beds were deposited. As the movement progressed, the sediments coming from the rising land surface to the west became sandy and invaded the basin, causing the deposition of the Cheyenne beds of Kansas and the lower Purgatoire formation of Colorado. The sands were more abundant in eastern Colorado than in Kansas, where they were more remote from the source, so that the more or less homogeneous sandstone (locally conglomeratic) of Colorado became interstratified with shale in the Kansas section. In Kiowa time this basin was invaded by the Washita sea with deposition of marine shales in western Kansas, while the corresponding interval in Colorado is also occupied by shales which are here much thinner. It is probable that while the center of the basin was receiving these sediments the western margin was either still receiving sand or that the shore line had advanced eastward by sedimentation. After the withdrawal of the Comanche sea sandy sedimentation was renewed in Dakota time throughout the basin, but the

sands continued to be thicker and more homogeneous toward the west than farther east in the basin.

The well drilled northeast of Garden City shows a thickness of 381 feet of Comanchean beds, consisting of alternating sandstones and shales, many of the latter being black. At the outcrop in Kiowa County the thickness is scarcely 200 feet and in eastern Colorado the Comanchean below the true Dakota is rarely more than 200 feet thick, though some exceptional local thicknesses are reported. It appears, therefore, that in the basin east of the Rockies beneath younger beds there are deposits of Comanchean age which are at least locally thicker than exposed at the outcrop and that these beds in the longitude of Garden City consist largely of alternating beds of sandstone and black shale.

The Cheyenne sandstone at its outcrop near Belvidere, Kiowa County, Kansas, is a white to yellowish, cross-bedded, saccharoidal sandstone. The Kiowa shales are chiefly dark to blue black and in the lower part becomes increasingly carbonaceous. Exposures weather out and resemble to some extent the paper shales of other regions, but though the term has been applied to certain beds in the Kiowa, the Kiowa shales are not so tough.

Permian and Pennsylvanian

The Comanchean rests unconformably on the Permian of Kansas. At the outcrop in the southern part of the state they overlie the Red Beds and in the northern part they rest on younger beds of the Permian. In the Garden City and Utica wells the Red Beds were encountered.

A deep well drilled at Vesper in Lincoln County, Kansas, starting almost immediately below the Dakota, penetrated the following strata at the depths indicated:

Strata penetrated in the Vesper well, Lincoln County, Kansas

	Thickness in feet	Depth in feet
Salt	136	742
Sand	24	1276
Sand	5	2302
Sand	13	2548
Sand	58	2755
Several thin sandstones		2887-2938
Sand	120	3215
Mississippian limestone		3335

The presence of Cretaceous beds and the western dip of the Carboniferous strata combine to make the depths to these horizons considerably greater in Logan and Gove counties than in Lincoln County. About 600 feet more of Permian beds are present in the Utica well than in Lincoln County.

The Permian consists of typical Red Beds, red sandstone, clays, shales and sandy shales with some limestone and beds of salt. A show of oil was reported in the Permian about 500 feet above the base in the Vesper well. In a well drilled north

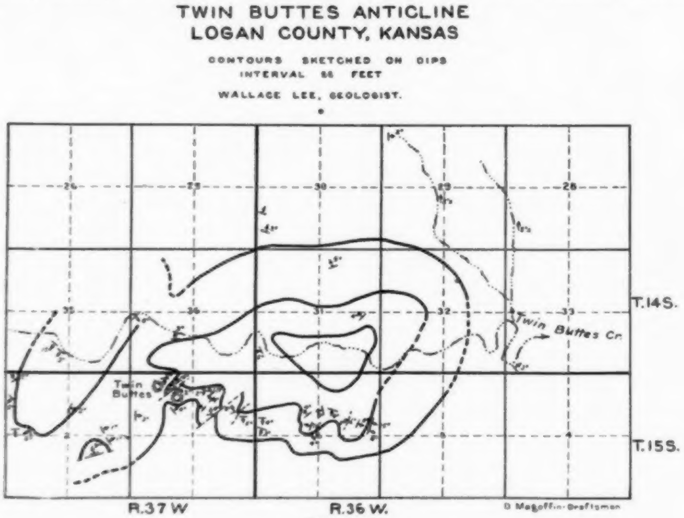


Plate II

of Collyer in Sec. 5, T. 11 S., R. 25 W., oil was found at a depth of approximately 1860 feet in a sand in the Red Beds about 400 feet from the top. Oil rose 300 feet in a 10 inch casing. While trying to pull the casing the top of the rig was pulled in and later the casing was pulled in two, and the well has not been completed. While the Permian is not considered as a probable source of oil, yet this amount of oil would suggest that oil might be found in the Permian in commercial amounts, particularly in connection with faults, as this oil is probably migrating upward through faults from the underlying Pennsylvanian.

The depth to the Permian and Pennsylvanian in the area special consideration in this paper will be much greater than at Vesper, due to the westward dip of the strata and to the presence of a greater thickness of the Cretaceous. The following table gives the approximate depths to the horizons reported in the Vesper well for the district including Scott, Lane, Ness, Logan, Gove and Trego counties, the figures being reckoned from the base of the Niobrara.

Approximate depth below Niobrara chalk of deep sands to be encountered in Scott, Lane, Ness, Logan, Gove and Trego Counties, Kansas

		Depth in feet
Top of salt		2200
Sand	24 feet	2800
Sand	5 feet	3800
Sand	58 feet	4250
Sand	120 feet	4700

The Vesper well is located 120 miles east of the area here under discussion and considerable variation may in consequence be expected in the thickness and number of sands.

In addition to the above sands in the Pennsylvanian there are a number of thick sands in the Permian portion of the logs of Utica and Garden City which, while not looked upon very favorably as oil reservoirs, may be regarded as possibilities.

Oil has been produced from the Red Beds of Permian and Triassic age in the following fields: Garber, Billings, Blackwell, Caddo-Cement, Lawton and Healdton, in Oklahoma; Burkburnett and Electra, in Texas; Dallas and Hamilton Dome, in Wyoming.

STRUCTURE

BLACK HILLS ARCH

The axis of the broad gentle arch which extends from the Black Hills of South Dakota across Nebraska in a southeasterly direction through Stockville and Cambridge, swings south and enters Kansas near the northwest corner of Norton County. From this place it gradually trends to the southwest and dies out south of Smoky Hill Valley. This arch was discovered by Darton[5], the fold being shown in a general

[5]Darton, N. H. The Structure of Parts of the Great Plains: U. S. Geol. Survey. Bull. 691A, p. 11, 1918.

way on Plate I in the report referred to just above. This broad arch is much concealed by beds of Tertiary, Quaternary and Recent ages through Nebraska and western Kansas, its position having been determined largely by drill holes. In southern Nebraska the exposures along Republican River, as pointed out by Condra[4], reveal the presence of this arch.

As shown on Plate I, Tertiary beds cover nearly all of

CHALK CREEK DOME
LOGAN AND SCOTT COUNTIES, KANSAS
CONTOURS SKETCHED ON DIPS
INTERVAL 50 FEET
L. R. VAN BURGH, GEOLOGIST.

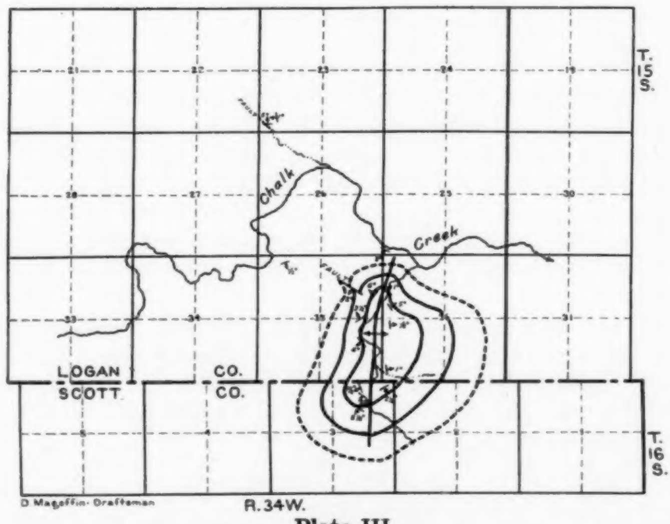


Plate III

western Kansas except along Smoky Hill River and some of its tributaries. This broad arch is registered here and has developed on it numerous minor anticlines and domes with their axis in general parellel to the axis of the broad arch.

MINOR DOMES AND ANTICLINES

Eighteen domes and anticlines have been mapped in the

[4]Condra, G. E. Geology and Water Resources of the Republican River Valley and Adjacent Areas, Nebraska: U. S. Geol. Survey Water Supply Paper No. 216, p. 11, 1907.

broad valley of the Smoky Hill River in Gove and Logan counties, Kansas. At least eight of these domes and anticlines are closed, with closure ranging from 50 to 150 feet. The presence of Tertiary beds and alluvium deposits prevented the determination as to the closure of several of the remaining structures.

These eighteen structures are situated in a belt ranging from 6 to 12 miles wide and 60 miles long. The most important structures are shown on Plate I by numbers 9-11 and 13-23. Plates II-VI, inclusive, show five of the eight structures known to be closed. These are the Twin Buttes dome, Chalk Creek dome, Elkader anticline, Hell Creek anticline, and Alanthus anticline. Their positions on Plate I are represented by numbers 9, 13, 16, 17 and 22.

The structure maps show the details upon which the contours were based.

Dip readings were taken on beds of chalk and iron bands in the Niobrara but no level lines were run on any beds. Definite zones can be recognized in the Niobrara but particular beds can not be followed far. The structure contours are presented to show the form and closure of the structures as represented by surface dips and are not drawn on any particular horizon.

It is believed that the subsurface structure in western Kansas is likely to be analogous to that of the ElDorado, Kansas, field recently described by Fath[5], in that the buried structures are much more pronounced than the structural condition at the surface indicate. For example, in the Shumway Dome the structure contours on the outcropping Ft. Riley limestone show a closure of about 30 feet, whereas in the same area the structure developed in the Stapleton oil zone 2500 feet lower shows a closure of approximately 130 feet. The same is true in the Cushing (Oklahoma) field described by Beal[6]

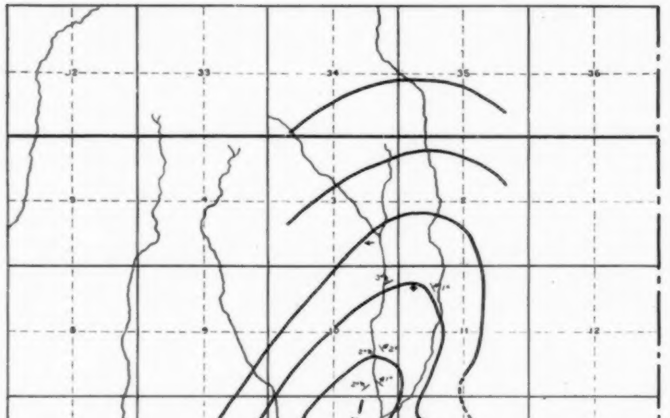
[5]Fath, A. E. Geology of the Eldorado Oil and Gas Field, Butler County, Kansas. State Geological Survey of Kansas Bull. 7, Plate XIV, 1922.

[6]Beal, C. H. Geologic Structure in the Cushing Oil and Gas Field, Okla., and its Relation to the Oil, Gas and Water. U. S. Geol. Survey Bull. 658, pp. 21-35, 1917.

ELKADER DOME
LOGAN COUNTY, KANSAS

CONTOURS SKETCHED ON DIPS
INTERVAL 25 FEET

WALLACE LEE, GEOLOGIST.



Dip and strike of beds
Flat beds
Beds flat in direction of strike

Plate IV

Fath[7] compiled data from Beal's contour map of four domes in the Cushing field, namely, Dropright, Drumright, Mt. Pleasant and Shamrock domes, which show that structures in beds 2550 feet beneath the surface have closures three to four times greater than the surface beds indicate. A study of the contour map of the Eldorado field (Plate XIV) also shows th atthe tops of buried domes are in nearly every case directly under tops of the domes represented at the surface.

MID-CONTINENT STRUCTURAL PROVINCE

The anticlines and domes present in western Kansas are believed to lie in the mid-continent structural province, where slight closures or even noses and structural terraces are sufficient to trap the oil. The area described in this report is situated between 240 and 300 miles from the Front Range of the Rocky Mountains to the west. A broad arch with its "high" near the northwest corner of Oklahoma and two corresponding synclines trend north and slightly east, thus separating this area from the Rocky Mountains.

FAULTS

Faults are very numerous, especially where structures are developed. The throw of these faults ranges up to 150 feet or more. Most of the faults are of the dip variety, or, in other words, they trend normal to the strike of the beds. Practically all of the faults belong to the normal type.

Where the throw is small, such as a few inches up to a few feet, the displacement may be caused by the readjustment of the brittle Niobrara chalk over the Benton shale, which may be folded without faulting, but when the faults have a considerable displacement it is believed that the faults are deep seated and probably are due to the rejuvenation of old deep seated faults or folds. The presence of oil in the Collyer well (Plate I, No. 6) in the northwest corner of Trego County confirms this theory. Oil in this well was encountered in a bed of sandstone in the Permian Red Beds. There is no

[7]Fath, A. E. The Origin of the Faults, Anticlines and Buried "Granite Ridge" of the Northern Part of the Mid-Continent Oil and Gas Field. U. S. Geol. Survey, Prof. Paper 128C, p. 82, 1920.

known source of oil in the Permian beds in this region, hence it is believed that the oil must have come from below or above. It seems doubtful if this oil migrated downward with the sandstones above containing water and no oil, hence it seems reasonable to assume that it migrated upward from the under-

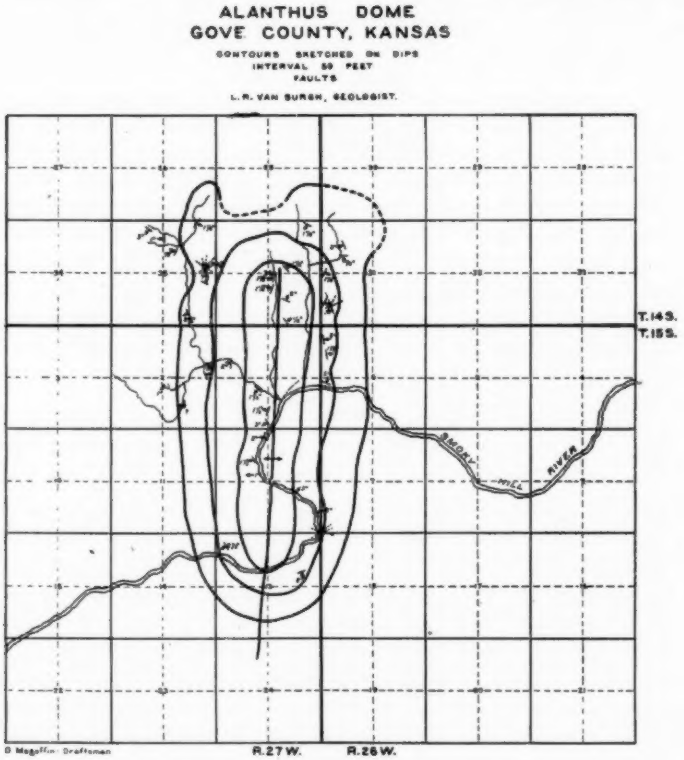


Plate V.

lying Pennsylvanian through numerous major faults which cut the structure near the well.

Many of the faults in the region are filled with calcite, showing plainly the imprints of the slickensided surfaces of the walls. Some of the faults contain a black gouge material

which, when tested for oil with ether, shows a brownish, greasy residue having an odor of vaseline.

IMPORTANCE OF FAULTING

Deep seated faults are of the utmost importance in an area like western Kansas, where the structures are underlain by beds of Pennsylvanian and Mississippian age rich in oil farming materials. The faulting not only permits a greater accumulation by fracturing the sandstone beds and facilitating the migration of oil into them, but also permits oil to migrate upward into reservoirs in the Permian and higher beds, as evidenced by conditions in the Collyer well. It is possible that sands as high in the section as the Dakota may be fully saturated with oil which has migrated from the Pennsylvanian and lower beds.

EVIDENCES OF OIL

The gouge material in fault planes indicates that some oil has come up through these breaks. The Collyer well (Plate I, No. 6) situated in the northwest corner of Trego County on Saline River encountered the largest amount of oil yet found in western Kansas. At a depth of about 1850 feet a sand containing oil was encountered in the Permian Red Beds. Although there were several feet of cavings in the hole and about 1000 feet of water, yet at least 300 feet of oil accumulated on top of the water in a 10-inch casing. The oil has a gravity of 36-37 degrees Baume as determined in the laboratory of the Midwest Refining Company. Practical oil men are of the opinion that this will be a commercial well when the water is cased off and the hole cleaned out and drilled a little deeper. Nothing has been done toward completing the well since encountering the oil, due to a reported controversy over acreage by various interested local groups.

Oil is reported in a shallow well near Athol in Smith County, Kansas, about 65 miles northeast of the Collyer well.

In the Garden City well (Plate I, No. 2) oil was encountered in small amounts in the Cheyenne formation of the Comanchean and also in a sand about 800 feet down in the Permian. It is reported that this well, which is still unfinished, has about 40 feet of oil in it. The structure at Garden City has a

closure of about 30 feet, as determined by surface dips.

Oil is reported in shallow wells along Republican River in Franklin and Harlan counties in southern Nebraska. Oil from these shallow wells comes out of the Niobrara and Pierre shales with water. The oil is transparent and ranges in color from yellowish white to cherry. Some of it is reported to contain as high as 50 percent gasoline.

DEVELOPMENT

Several wells have been drilled in the area and in nearby localities. The location of these wells and the location of the structures mapped in the area are shown by numbers on Plate I.

No. 1 is the Plateau Oil Corporation well in Sec. 27, T. 15 S., R. 31 W., on the Hell Creek Anticline.
No. 2 is the Garden City well in Sec. 35, T. 21 S., R. 31 W.
No. 3 is the Utica well in Sec. 1, T. 17 S., R. 26 W.
No. 4 is the Vesper well in Sec. 10, T. 12 S., R. 9 W.
No. 5 is the Red Cloud well drilled on the north edge of the town.
No. 6 is the Collyer well in Sec. 5, T. 11 S., R. 25 W.
No. 7 is the Chappell well in Sec. 6, T. 14 S., R. 34 W.
No. 8 is the Wray wells, the deeper one in Sec. 14, T. 2 S., R. 43 W.
No. 9 is the Twin Buttes anticline.
Nos. 10 and 11 are two unclosed structures.
No. 12 is the structure on which the Chappell well is drilling.
No. 13 is the Chalk Creek Dome.
Nos. 14 and 15 are unclosed structures.
No. 16 is the Elkader Dome.
No. 17 is the Hell Creek structure.
No. 18 is Hell Creek extension.
No. 19 is an unclosed structure.
No. 20 is Little Dome.
No. 21 is an unclosed structure.
No. 22 is Alanthus Dome.
No. 23 is Alanthus extension.
No. 24 is Liberal well.

The Plateau well on the Hell Creek structure has reached the depth of 2658 feet and has almost reached the first thick salt in the Red Beds. No oil has been encountered. It will be drilled deeper to test the upper sands of the Pennsylvania. It started in the upper part of the Niobrara. The Garden City well was drilled to a depth of approximately 2280 feet and stopped in the Permian Red Beds. Shows of oil were reported in the sands of the Cheyenne and in the Permian. It started near the base of the Niobrara. The Utica well was drilled to a depth of 2700 feet, stopping in the lower part

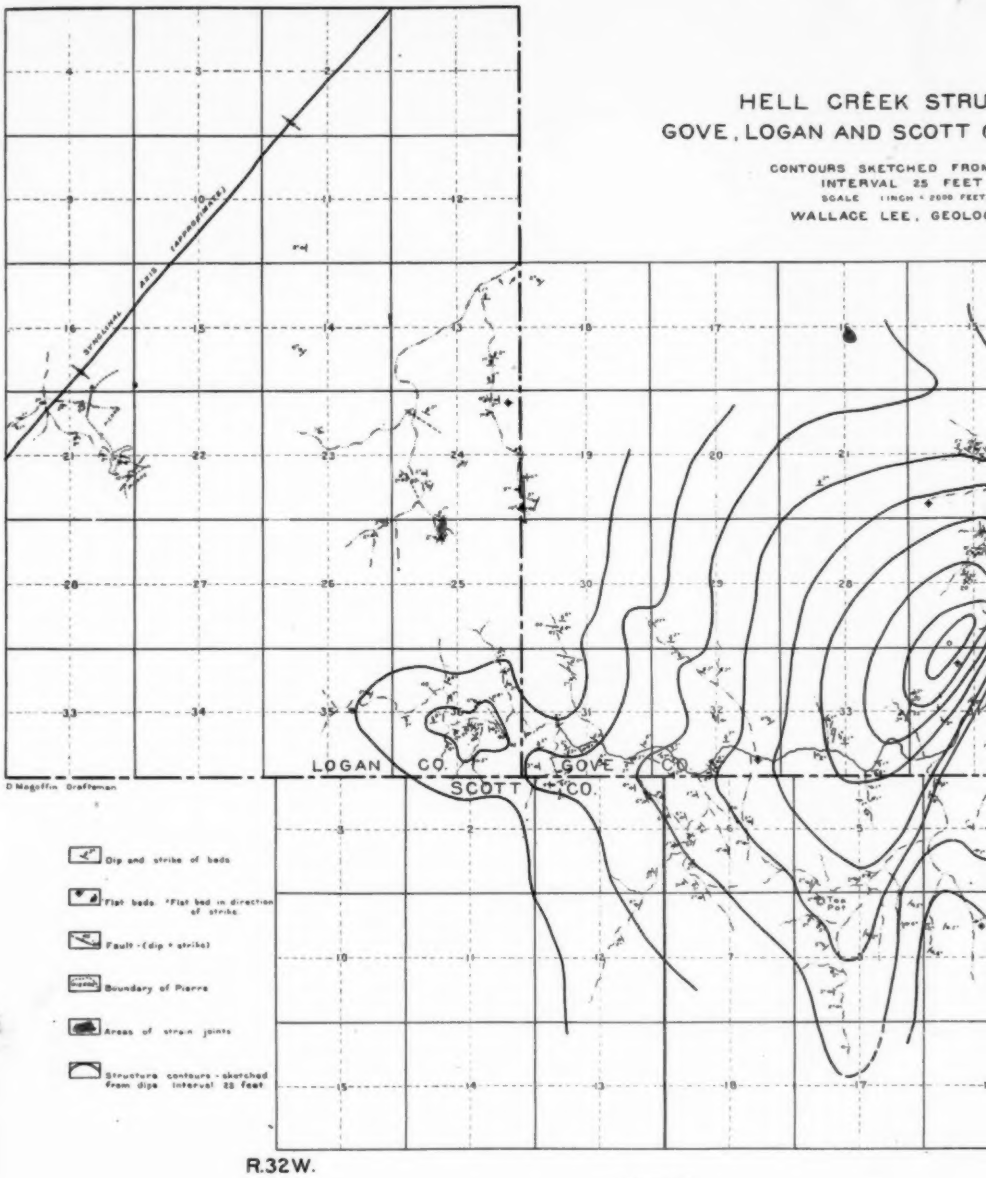
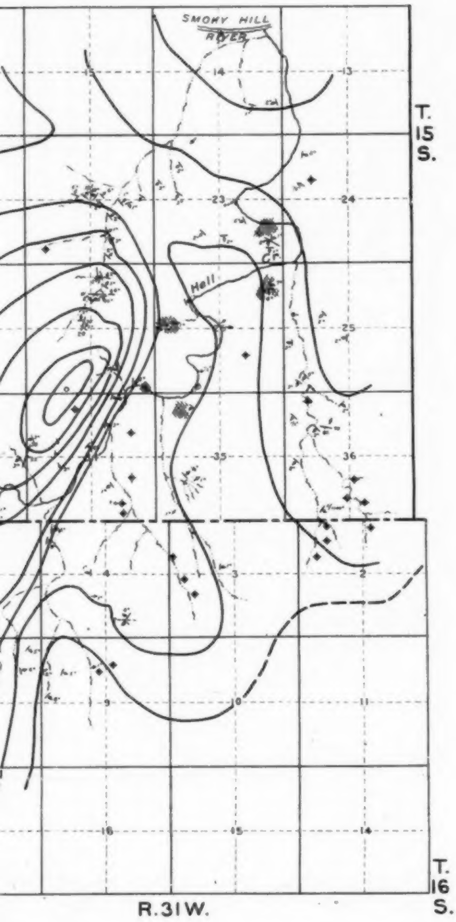

HELL CREEK STRU
GOVE, LOGAN AND SCOTT C
CONTOURS SKETCHED FROM
INTERVAL 25 FEET
WALLACE LEE, GEOLO
LOGAN CO.
GOVE CO.
SCOTT CO.
SYNCLINAL AXIS (APPROXIMATE)
D Magoffin Draftsman
Dip and strike of beds
Flat beds. *Flat bed in direction of strike
Fault - (dip + strike)
Boundary of Pierre
Areas of strain joints
Structure contours - sketched from dips interval 25 feet
R.32W.

Plate VI.

EK STRUCTURE
SCOTT COS., KANSAS

TCHED FROM DIPS
AL 25 FEET
INCH = 2000 FEET
LEE, GEOLOGIST



WEST. KANSAS WELL LOGS

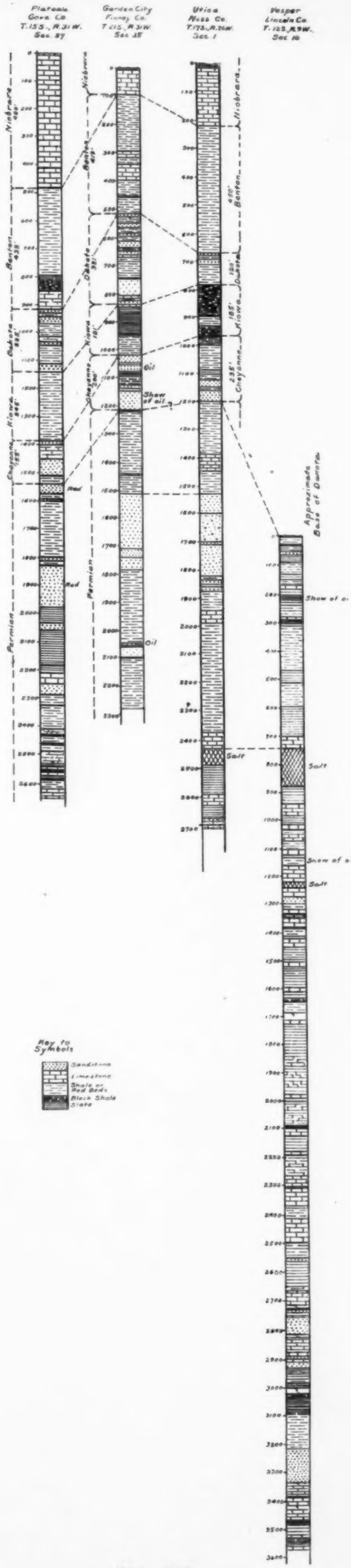


Plate VII.

of the Permian Red Beds. The Vesper well was drilled 120 miles east of the area and is the closest well drilled through the Pennsylvanian. So far as known it was not located on structure. It was drilled to a depth of approximately 3600 feet and stopped in the Mississippian. Several shows of oil were reported in the Permian Red Beds. It started almost immediately below the Dakota. The Red Cloud well in southern Nebraska started in the lower part of the Niobrara and went to a depth of 3460 feet. A well was also drilled at Riverton, about 18 miles west of Red Cloud. This well started in the upper part of the Niobrara and stopped at approximately 1600 feet. The Collyer well started in the upper part of the Niobrara and drilled to a depth of about 1860 feet, where a considerable quantity of oil was encountered in a sand in the Permian Red Beds. The Chappell well started in the Niobrara and at the last report was down 1400 feet. Three wells were drilled near Wray, Colorado, starting in the Pierre. The first was drilled 3650 feet and struck gas in the Niobrara at 1490 feet and a show of oil at 2430, possibly in the Dakota. The other two wells were drilled to 1590 and 1607 feet, where each encountered over a million cubic feet of gas in the Niobrara. One of these wells was being deepened at the last report. Gas is also reported in a well near Liberal, Kansas.

The Plateau well is located on a well developed structure having 150 feet of closure. The Garden City well is located on a structure which was not examined by the writers but is believed to have a closure of 30 feet. The Utica well is not believed to be located on a favorable structure. Nothing is known by the writerrs about the structural conditions at the Vesper well or that at Red Cloud. The Riverton well is located on a slight anticlinal fold. Whether the fold is closed could not be determined. The area around the Collyer well was not examined by the writers but the well has been reported to be located on structure, much faulted. The Wray gas wells were visited by the writers but no examination was made and no favorable structure was noticed, the area being greatly covered by Tertiary and alluvium.

POSSIBLE SOURCE OF OIL

It is possible to penetrate the upper 1000 feet of the Pennsylvanian by drill holes 4000 feet deep, and all of the Pennsylvanian and part of the Mississippian by a 5000 foot hole, if the section corresponds to the Vesper log.

It is well known that the main source of oil in the Mid-Continent region is in the Pennsylvanian and Mississippian. It is probable that this same condition holds for western Kansas.

The beds of Permian age in this region constitute a poor source of oil but they contain sands capable of serving as good reservoirs for oil coming up from lower formations.

The Kiowa shale in the upper part of the Comanchean may be a source of oil, as it is black and is rich in carbonaceous material.

SUMMARY

The productive oil fields of Kansas are limited to the southeast one-sixth of the state. The western half of the state to date has no proven commercial oil well, although the Collyer well in the northwest corner of Trego County may prove to be one.

The surface rocks in western Kansas are mainly of Tertiary age. Wherever the veneer of Tertiary beds has been eroded through, Pierre shale and Niobrara chalk are exposed, the former, however, only in small areas.

The best exposures of Cretaceous beds are present in a belt 6 to 12 miles wide and 60 miles long in Logan and Gove counties in the valley of Smoky Hill River. In this particular belt 18 structures are developed on the broad gentle arch which connects with the Black Hills. Eight of these structures are known to be closed and some of the others may be, as in some cases their ends are covered with Tertiary beds and alluvium. The closures of the closed structures vary from 50 to 150 feet.

Faults are numerous and many are believed to be deep seated, thus permitting oil if present to migrate upward from the Pennylvanian and Mississippian beds, which are believed to be the main source of oil in the region. The presence of

oil in the Permian on the Collyer well on a much faulted structure strongly suggests that this oil came up through faults from the Pennsylvanian or lower beds.

Holes drilled to a depth of 4000 feet would penetrate about 1000 feet into the Pennsylvanian in practically all of the structures in case oil was not found at shallower depths.

The writers believe the area lies well inside the mid-continent structural province where slight closures trap and hold oil, and that the conditions here will be found to be similar to Eldorado, Kansas, and Cushing, Oklahoma, in that more pronounced structures will be found in the Permian and Pennsylvanian than the surface beds indicate, and that these subsurface structures will be found directly beneath the surface structures.

In such a region as western Kansas, (1) where well closed domes and anticlines are developed, (2) where indications of numerous deep seated faults are present, (3) where a rich source of oil is buried within reach of the drill, and (4) where a little oil already has been found, it seems reasonable to expect more oil will be encountered in further drilling in favorable localities.

DISCUSSION

SIDNEY POWERS: The statement is frequently made that oil found in "red beds" has migrated from non-red sediments. As petroleum exploration progresses, more and more oil is found in the "red beds," where it is not supposed to be native and distillation of red shales is said to have yielded oil. It therefore seems necessary to admit that oil may originate in red beds. Moreover, sediments of red color may be deposited under terrestrial, lacustrine and marine conditions and aridity is a common yet not an essential climatic condition. Until more is learned regarding "red beds" it is not safe to condemn any of them as an original source of oil, merely because of the red color.

CHARLES T. KIRK: (1) Answering Becker's question to Powers as to whether there is any bituminous matter reported from the Permian of the Midcontinent: The Delaware limestone of southeastern New Mexico is quite well filled in places with oleaginous matter and has a bituminous odor when freshly exposed.

(2) The principal speaker in selecting Eldorado, Kansas, appears to have taken a special instance where the sub-surface doming is directly under that on the surface. Notable examples exist of production considerably to the west of the surface axis, as in the Sallyards region of the

Flint Hills in western Greenwood and eastern Butler counties, Kansas, and in the Urschel pool. Both these areas are not far removed from the region where Mr. Lupton appears to predict production immediately under the surface anticlines.

W. E. WRATHER: There is considerable evidence locally of the presence of organic material in the midst of the Red Beds. On the northwest side of the Wichita Mountains near Granite Oklahoma, dark colored oil shales appear interstratified with typical red beds. These shales may be seen in the banks of a creek northwest of Granite. The individual strata are seldom more than a few inches thick. Although I know of no analyses having been made, there seems to be a high percentage of bituminous matter present.

WARNER NEWBY: A sample of shale taken a few miles south of Electra Texas, from just below the Beaverburk Limestone of the Wichita Formation was analyzed and found to contain three-fourths of one per cent of carbon. Shales of this character are fairly common in the Wichita Formation and I see no reason why they could not be the source of most of the oil obtained from it.

F. G. CLAPP: Besides the evidences mentioned by Mr. Lupton, other evidences exist that the Carboniferous is likely to be productive under portions of western Kansas, western Nebraska, northwestern Oklahoma and eastern Colorado. These evidences consist, first, of the fact that the Permian series of western Kansas and western Oklahoma does not appear to have been a source of oil, but that the oil has apparently been derived from its upward migration from the underlying Pennsylvanian rocks; hence the showings of oil in wells of the Permian in western Kansas may indicate greater deposits in the Pennsylvanian of those regions. Secondly, oil wells of great volume have been struck in the Soap Creek dome in Big Horn County of southern Montana; and these, when considered in connection with the Permian production in the vicinity of Lander, Wyoming, and Hamilton dome in the same state, prove the existence of great resources of oil, hitherto unsuspected, in the Carboniferous rocks of the northwestern United States. Since the Carbonifercus is highly productive in eastern Kansas and also in southern Montana, there seems to be no particular reason why, the rocks of the same series in the intervening region are not likely also to be productive.

WALLACE E. PRATT: Is the gas at Amarillo necessarily Pennsylvanian, as Mr. Clapp appears to suggest? So far as my information goes, there is no proof of the presence of Pennsylvanian beds at Amarillo. There are organic shales and limestones in the known Permian beds at Amarillo. There are hundreds of feet of black shales beneath the gas-bearing limestone at Amarillo, which have not been shown to be Pennsylvanian so far as I know, and which lithologically resemble closely the known Permian section elsewhere in Texas.

There is oil in known Permian rocks of organic character in southwest

Texas. This oil may be shown clearly to be of Permian origin. There is oil in Permian rocks in Mitchell County, Texas, much closer to the Amarillo field. I know of no reason to assign this oil to a source other than the series in which it occurs.

Why then, if oil and gas occur originally in Permian beds in Texas should we assume other than a Permian source for oil or gas in Permian rocks elsewhere in Texas, without definite evidence of such other source?

DR. CHARLES SCHUCHERT discussed briefly the age of the buried formation of western Kansas and the significance of paleogeography.

W. C. KITE: Several geologists, in experimenting with "red beds" shales, have reported the presence of oil, however, it may be as Dr. Schuchert suggests, that these "red beds" are Pennsylvanian and not Permian. To me, the first point of interest is the fact that there is oil in these "red bed" shales and it is of little concern whether they be Pennsylvanian or Permian.

JOHN L. RICH: As has just been pointed out by Professor Schuchert, there are strong reasons for thinking that the Pennsylvanian rocks may be absent from at least part of the area of western Kansas, under discussion.

In northeastern New Mexico a well drilled in 1919 encountered granite immediately beneath the red beds. This well was located on the broad ge-anticline east of the Raton Basin. This broad belt of uplift—a buried granite mountain range of probable late Pennsylvanian or early Permian age—extends northward into Colorado toward the area under discussion. Therefore, the partial or total absence of the Pennsylvanian in that area is a possibility which should not be overlooked.

Inasmuch as the Permian San Andreas formation and its equivalents of New Mexico and Texas is petroliferous, it does not seem necessary to suppose that absence of the Pennsylvanian precludes the possibility of finding oil.

MAX W. BALL: There is no magic in the word Pennsylvanian; no black magic in the word Permian. Oil forming material may be present or have been present in the latter as well as the former. For example, the pre-Cretaceous oil source of Wyoming is, according to Dr. Girty and the U. S. Geological Survey, Permian. This source, which is in the formation variously called Embar, Park City and Phosporia, was formerly considered Pennsylvanian, but fossil evidence obtained during the past few years, chiefly in connection with phosphate investigations in this formation, has led Dr. Girty to conclude that the formation is Permian. Thus, the pre-Cretaceous oil of Wyoming, at least the major part of it, must be considered as of Permian rather than Pennsylvanian origin.

The most persistently saturated pre-Cretaceous sand of Utah is the Moenkopi, which contains both Permian and Triassic formations. This formation has two facies, one red, the other tan. The former is seldom oil saturated; the latter contains some oil at most places where it out-

crops. The red phase contains Triassic forms; the tan phase contains forms of possible Permian affiliation. At most localities the red phase is above, the tan below, and this led for a time to an assumption that the upper part of the formation is Triassic, the lower Permian. Later study, however, discovered localities when the red phase is present at the base as well as the top, and at these localities undoubted Triassic forms were obtained at the bottom of the formation. From the evidence available the entire formation is Triassic. Thus in Utah, as in Wyoming, the principal pre-Cretaceous oil source is post-Pennsylvanian.

E. G. Woodruff: There are considerations which cause some of us to view western Kansas with less optimism than Mr. Lupton does. As far as known, the strata which might be expected to produce petroleum in western Kansas were deposited in deep sea marine waters. Formations of this character are not known to produce oil generally. They do not afford vegetable or animal material from which oil is derived and do not embrace sands in which the petroleum can be reservoired. If there are sands in such deposits the pores are filled with clay or lime rendering the sands non-porous and therefore not fit to serve as reservoirs for liquids.

Thus it seems that in western Kansas there are lacking two essentials for oil fields, namely a source of petroleum and a reservoir body. Wildcatting may find an old granite ridge or hills, but until they are found the region must be viewed with doubt.

Clyde M. Becker: The remarks of Mr. Woodruff stir my memory. I cannot but recall the recommendations of ten years ago of the best geological minds relative to the finding of oil in the Red Beds of Oklahoma.

K. C. Heald: While seeking the rainbow's end in the Paleozoic rocks of western Kansas, the possibilities of oil in the Cretaceous must not be overlooked. The basal beds of the Upper Cretaceous are impregnated with oil in many localities along the Rocky Mountain front, and these same oil-forming conditions may persist far to the east. The chances of oil in the Pierre shale, of Montana age, must also be considered. It is true that the Pierre is not uniformly oil-bearing, but the Florence field of Colorado and the production from the Shannon sand in central Wyoming furnish substantial proof that much oil can come from the Pierre shale in restricted areas. Certainly there is as yet insufficient evidence to justify the statement that such an area does not exist in western Kansas or Nebraska.

DIAMOND DRILLING FOR PRODUCTION

FRANK A. EDSON

The drilling of a 1200 barrel well by the use of the diamond drill, accompanied by the securing of some 85 percent of core and a substantial saving in drilling costs, has been a matter of considerable comment among both operators and geologists. Since the work was done under the actual direction of the writer, he has thought that an account of the operation would be of interest both to members of the Association and to oil men in general.

The well was drilled for the Panuco-Boston Oil Company, a subsidiary of the Atlantic Refining Company. It was located on the Ugarde lease in the Panuco district of Mexico, about 40 kilometers from Tampico. The formation is similar to that found elsewhere in the district. There is about 200 feet of surface soil, mainly river wash, which contains some boulders. Underneath this there are about 1200 feet of shales, presumably Mendez, underlaid by some 700 or 800 feet of the shaly limestone of the San Felipe series. These lie directly upon the Tamosopa limestone, which, however, was not penetrated by the drill as the production was found before this formation was reached. Judged from a drilling standpoint the upper 1400 feet is good rotary ground, although it can be drilled with cable tools. Below this depth the ground is much better for standard than for rotary tools.

The upper part of the formation, down to 1407 feet, was drilled by attaching a fish-tail bit directly to the diamond drill rods by a special bushing and operating as an ordinary rotary. The customary mud-laden fluid was used, an ordinary mud pump being employed for this purpose. The main points of difference between the diamond drill and the rotary in this part of the work was the manner in which the drill stem was rotated, and the way in which it was held in suspension.

The drill stem, or "rods," as they are called in diamond drilling, is directly connected to the engine by bevel gearing very similar in type to that used in the modern gear-driven

rotary. The effect is to give a higher speed of rotation to the bit, the diamond drill ordinarily running from 200 to 400 revolutions per minute, while the rotary normally averages between 60 and 100 revolutions per minute. This higher speed must generate greater centrifugal force, which slaps the mud against the side of the wall somewhat harder than does the ordinary rotary. This is a point which it is probably impossible actually to demonstrate, but rotary drillers with whom the writer has discussed the matter all agree in thinking this to be of practical benefit to the hole.

The drill stem is made up of flush-jointed steel rods, which are of uniform outside diameter. These rods are passed through a chuck, which, while being free to revolve, is attached to a hydraulic cylinder. This cylinder moves vertically either upward or downward, carrying the rods with it. In effect it is a hydraulic jack which carries the weight of the rods and yet allows them to revolve freely. As the water is allowed to escape from the under side of the hydraulic piston the drill stem moves gradually downward, or, if the direction of the flow in the cylinder is reversed, it moves upward. The escape of the water is controlled by a valve and is capable of a very fine adjustment. This method allows the operator both a more positive and a more delicate control of the movement of the drill stem than is enjoyed by the rotary driller. This was well illustrated by a fishing job which occurred at 2100 feet. At that depth the top of the core-barrel, which had been obtained locally and contained defective material, twisted off. A screw tap was attached to the rods, and the engine revolved at the slowest possible speed, while the driller fed the drill stem down so delicately that it entered at the proper speed to firmly thread its way into the inside of the core-barrel. Incidentally the entire operation took only a little over seven hours.

This absolute control of the downward movement of the drill stem enabled the drill to go through gumbo without "balling up." The secret is to feed the bit down evenly and slowly so that it cuts the ground a little more slowly than the pump can take it away. If this is properly done there is no danger of a ball up for there are no cuttings there to ball up.

The value of being able to go through soft ground without being troubled in this way is hard to overestimate.

The cuttings were much finer than those obtained from ordinary rotary drilling. Probably 80 percent would go through a 50 mesh sieve. This is probably due both to the higher speed and the more even feed of the diamond drill. The finer cuttings undoubtedly work farther back into porous strata and thus mud up the hole better. On the other hand they do not afford as much information to either the geologist or the driller. Mr. Elledge, the geologist for the Panuco-Boston, complained that when he washed the samples he had nothing left. When the diamond drill uses the fish-tail bit the log will be even less reliable than the ordinary rotary log because of this fact.

The hole was cased with three lines of casing. For surface conductor 223 feet of 7⅝-inch pipe was used. Inside of this was placed 548 feet of 6-inch pipe, while the final string was 1407 feet of 4-inch pipe. The casing was all of the ordinary type, no flush-joint being used. The 6-inch pipe was an unnecessary precaution taken because this was the first hole ever drilled in this way. It is being omitted on succeeding holes. The 4-inch pipe was cemented into the lime in the ordinary way by the use of a top and bottom plug. The cementing was done in accordance with the Mexican government regulations, and under its supervision. It is required on all wells drilled in the high pressure areas. In conformity with these regulations the cement was allowed to set for ten days before being drilled out.

In the upper part of the hole difficulty was encountered because the drill stem, 2⅜ inches in outside diameter, was too small for the large size hole which the drill was then making. The side play of the stem caused frequent breakages. This was temporarily remedied by using 4-inch rotary drill stem with only enough diamond drill rods to make the connection through the hdraulic cylinder. Drill stem of a diameter of 3½ inches had been ordered from the manufacturers, but had not arrived at the time the writer left Panuco.

Diamond drill rods are ordinarily unscrewed by hand, using a 36-inch pipe wrench, and the machine was not equipped with

mechanical means of breaking joints. This slowed up the operation of coming out or going into the hole, as breaking apart rotary tool-joints by hand is a slow and laborious process. Also the drilling was, perhaps, slowed up somewhat by the fact that the downward pressure of the hydraulic could not be used on the rods without danger of breaking them. This, of course, would only apply to the upper part of the hole. No records were broken so far as an individual day's run was concerned. The average cutting speed with the fish-tail bit was from 10 to 18 feet per hour, depending upon the formation it was working in. It is probable that, with the use of the proper drill stem and the greater familiarity of the crew with the operation, a speed of from 150 to 200 feet per day can be averaged.

After drilling out the cement, work was carried on by the aid of the diamond bit. A 3⅝-inch bit, which cuts a 3-inch core, was used. None of the holes in the Panuco district are cased below the top of the lime, so it was unnecessary to carry a larger hole.

A 13-foot core-barrel was used, which necessitated coming out of the hole several times a day. An average speed of approximately 75 feet per day was maintained down to 1850 feet, where enough oil was struck to fill the hole. From there down to 2153 feet, where the hole was bottomed, the drill averaged between 35 and 40 feet per day. The former average was somewhat above the average of cable tools in this district, while they can only make from 8 to 10 feet per day when drilling in a hole full of oil. Lest the Panuco cable tool driller be unjustly criticised, it should be remembered that Panuco crude is of about the consistency of molasses and very effectually cushions the blow of the bit.

A cutting speed of approximately 10 feet per hour was made by the diamond bit. The loss of speed came from the time required in coming out and going back into the hole. At 1500 feet it took about 45 minutes to come out and about 35 minutes to go into the hole. When the hole was full of oil it took nearly two hours to pull out and about the same length of time to go in. A 64-foot steel derrick was used, which allowed the rods to be pulled in 50-foot lengths. The speed of

the drill is governed more by the number of times it is necessary to pull out, and by the length of time required for this operation, than by any other factor. The number of times it is necessary to pull out is governed largely by the length of the core-barrel. A 30-foot core-barrel is to be used on the next hole, and it is very probable that an average speed of between 100 and 125 feet per day will be maintained.

Considerable doubt was expressed as to whether or not the drill would operate satisfactorily when the hole was full of oil, and if the drill stem might not be blown out of the hole when the high pressure was encountered. The oil in the hole seemed to act as a lubricant on the rods, and, if anything, the drill worked more smoothly. On the other hand, while an oil-saver was used when the drill was running, it had to be removed to take the core-barrel out and the derrick and floor became so covered with oil that it was almost impossible for the men to keep their footing. This was the main reason why not over 40 feet was made per day, as the cutting speed of the bit was approximately the same as before.

The high pressure gave no particular trouble except that the last 500 or 600 feet of drill stem had to be snubbed out of the hole with a manila rope. It was unnecessary to use the more elaborate apparatus which had been provided for this purpose. While not over 750 pounds of pressure was encountered the writer has no hesitancy in stating three or four times this amount could have been satisfactorily handled. The secret is never to let the well get away from you.

To the surprise of everyone about 85 per cent of core was obtained. This was due both to the large size of the core and to the flat bedding of the rocks. Probably no one feature of the drilling attracted as much attention as the core. It was a new and satisfactory experience to both operators and geologists to be able to see and handle the rocks which were actually producing the oil. Many of the cores contained fractures which, when broken open, were found to contain drops of oil. Sometimes the gas could be seen bubbling out of the core. As the drill reached greater depths the fractures contained more and more oil, until at about 1850 feet they began to give actual production. The well came in rather grad-

ually from that point until at 2153 feet enough oil was struck to bring the production up to 1200 barrels.

It was observed that these fractures occurred in zones. The drill would penetrate 20 or 30 feet of fractured ground and then go back into solid rock again. This would continue for 50 or 60 feet and then another fracture zone would be encountered. This information would have been very important had it been desirable to shoot the well. The shooter would have known, almost to the inch, just where to put the shot, and could have judged much more accurately as to the amount of explosive required. In general it is hard to overestimate the practical value of the information to be obtained from such cores. The ordinary practical oil operator can obtain more information from them than the trained geologist does now from a microscopic study of well cuttings.

Doubt was also expressed as to whether or not the 4-inch pipe would be large enough to accomodate the oil. As stated above the well came in with 1200 barrels, but the oil coming out of the pipe did not fill more than one-tenth of its area. There may be occasional wells so large that a 4-inch pipe really will not accomodate the oil, but they are few and far between.

An interesting discovery was the fact that the ordinary mud-laden fluid which is used by the rotary can also be used with a diamond bit. It has generally been thought that the latter would require clear water, but about a 20 percent mud solution was used in this hole with satisfactory results. It is probable that even thicker mud could be used if larger waterways were cut in the bit. The fact that mud can be used with a diamond bit makes it possible to drill in caving formations, recover the core, and at the same time hold up the sides of the hole with mud. This makes the diamond drill practicable for softer ground than has been thought before. Just what the limits are in this respect is yet to be worked out.

An equally welcome discovery was the fact that a very considerable saving was made in costs. The hole was completed for less than $25,000, which is to be contrasted with $42,500 the contract price at that time in the field. This figure covers the complete cost,—fuel, water, casing, rig, labour,

diamond wear (which amounted to less than one cent per foot), being all included—a "turnkey job" in other words. It should also be remembered that neither the writer nor any of the drillers had ever been in the Panuco field before, so the well was to all intents and purposes a wildcat to them. The writer has no hesitation in stating that as the men become more familiar with the work and develop the technique required in this field the costs will be cut to fifty percent of those of drilling by ordinary methods.

It should be noted that the well was cored all the way through the lime. Had the plugged bit—which is solid and takes no core—been used it is probable that an even greater cut would have been made in the cost of this well. The writer has talked with drillers who have worked in both the Panuco and the Mid-Continent fields. They unite in stating that the rocks in Panuco drill just about the same as the average rocks of the Mid-Continent. He is, therefore, inclined to believe that a very substantial saving can be made in drill costs in the latter as well as in the Mexican fields.

The writer also had charge of a diamond drill in the Southern Fields, which was doing structure drilling. This outfit had just gotten nicely started when he left Mexico, but one observation was made which is of importance to the Mid-Continent operator. The drill was operating in the upper part of the Alezan shales, which are fully as soft as the ordinary rotary ground in this country. Men who have operated in both places say that they are about equivalent to the softer portions of the Redbeds. Yet by taking certain precautions over 95 percent of core was obtained with a single-tube core-barrel. From this experience it is believed that no great difficulty will be encountered in obtaining cores from either the softer shales or sands of the Mid-Continent fields.

NOTE: Discussion of Mr. Edson's paper is included with that on Mr. Longyears article which follows:

THE DIAMOND DRILL IN OIL EXPLORATION

By Robert Davis Longyear

The recent success of the Panuco-Boston Oil Co. in bringing in a 1200-bbl. well with a diamond drill in the Panuco District, Mexico, has aroused the interest of oil men in all parts of the country, and diamond drill manufacturers are receiving an increasingly large number of requests for information on the use of the diamond drill for oil work. In view of this interest it has seemed desirable to submit the following remarks on the general advantages of the diamond drill, substantiated with definite illustrations. The writer is indebted to Lynch Bros., diamond drill contractors of Seattle, to the Diamond Drill Contracting Co., of Spokane, and to E. J. Longyear Co., diamond drill manufacturers and contractors, of Minneapolis, from whose experience most of the data have been obtained.

The details of the bringing in of the Panuco-Boston well are described in a paper prepared for the Seventh Annual Meeting of the American Association of Petroleum Geologists by F. A. Edson, who had charge of the diamond drill work for the Panuco-Boston and Cortez Oil Companies. It will therefore not be described here except to state that this well was drilled to a depth of 2153 feet at a cost, according to Edson, of approximately 60 percent of the price asked by cable tool and rotary contractors in the same district. Elledge[1] has also given a very good description of this well.

The diamond drill can be used for drilling wildcat wells or wells in proven fields either as a distinct outfit or as an interchangeable unit in connection with other methods. It has also a considerable range of usefulness as an aid to geological structure-mapping by drilling shallow holes to determine elevations on key horizons. Although it appears to have been

Robert Davis Longyear, Geologist, E. J. Longyear Company, Minneapolis, Minnesota.

[1]Elledge, Geo. A., The diamond drill in oil field practice, Oil & Gas Jour., Vol. 20, No. 30, Dec. 23, 1921.

demonstrated that in Mexico the diamond drill can be used in drilling wells in producing fields, yet its chief interest to operators and geologists in the Mid-Continent and other districts of the United States and Canada lies in its adaptability to oil exploration.

LOWER COSTS

The advantage that means the most to the practical oil man is the lower cost of drilling wildcat wells. The diamond drill

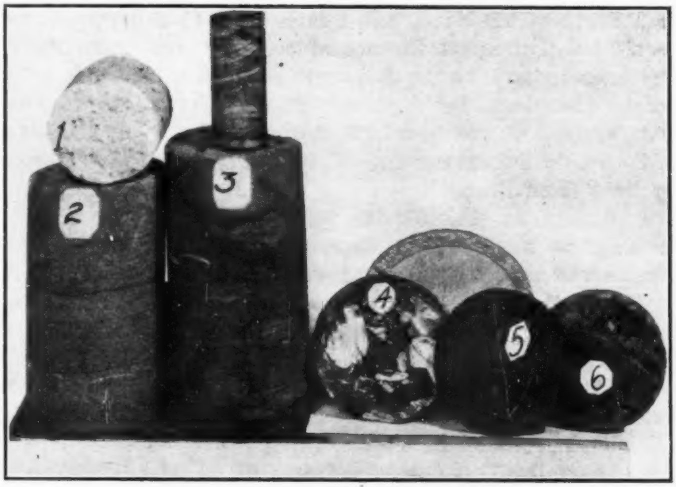


Plate I. Diamond Drill Cores Recovered in Oil Exploration
1. Gas Sand, Shelby, Montana.
2. Fine Sandstone, showing stratification, Kremlin, Montana.
3, 4. Fossil Shells, Kremlin, Montana.
4, 5. Fossil Leaves, Ferndale, Washington.

secures a lower cost in three ways: (1) Transportation charges are lower because the weight of the outfit is considerably less than the weight of other types. (2) The diamond drill uses fewer strings of casing, thus making a great saving in casing costs. (3) The cost of operation is usually less in wildcatting.

Transportation.—The cost of moving a cable tool or rotary outfit into an out-of-the-way locality is one of the large fac-

tors in the cost of test wells. A cable tool outfit to drill 3500 feet weighs around 250 tons, and a rotary outfit 350 tons. A diamond drill outfit of the same capacity weighs only 60 tons. On a cable tool test in Utah the transportation charges alone amounted to over $100,000, and other wells in this state have been similarly expensive.

Last year Lynch Bros. shipped a diamond drill outfit into the Peace River District for the British Columbia Provincial Government. This outfit was capable of drilling 3-inch holes to a depth of 1200 feet and 2-inch holes to a depth of 2000 feet. No figures on the actual cost are available, but the writer is informed that the outfit weighed thirty tons. This included sectional boiler, camp, supplies for all winter, drill rods, tools, 1000 feet of 3-inch flush joint casing, and 2000 feet of 2-inch flush joint casing. The outfit was shipped 250 miles by boat from Peace River. and then 26 miles on horse-back over tundra so soaked with water that in places only one hundred pounds could be carried by a horse. Drilling was commenced in 47 days after leaving Peace River. From 700 to 1100 feet has been drilled each month, the highest footage being made in December with the thermometer standing at 45 degrees below zero. It would have been impossible to have taken a standard rig into the site without building a road over the 26 miles of water-soaked tundra. The cost would have been prohibitive.

In the fall of 1920 to a more easily accessible locality in the same district, a standard rig was moved in on sleighs, and up to August, 1921, had drilled a total of only 800 feet. The diamond drill started nine months later, and at the same date had drilled over 2500 feet.

Casing.—The diamond drill uses smaller sizes and fewer strings of casing than the cable tool drill in holes of equal depth. This reduces the cost of a very important item in the expense of a test well. Flows of water do not interfere with the actual operation of the drill and therefore do not have to be cased off until the oil or gas sand is to be tested.

Under-reaming has proved successful with diamond drilling. In one hole now being drilled in the northwest a three inch casing has been under-reamed to date from 160 to 1860

feet, the bottom of the casing being kept within 10 to 20 feet of the bit for the greater part of the distance. Under-reaming is accomplished by means of a special diamond bit that is expanded by the hydraulic pressure of the circulating water. It can be used either by itself at the end of the rods, or in conjunction with the ordinary bit by being coupled to the top of the core barrel.

The sizes of casing selected depend on the depth to be attained and upon the local standard of sizes of the smaller strings of oil well casing. For sizes under 5 3-16-inch it is preferable to use oil well tubing or diamond drill flush joint casing rather than water well casing. The latter is not strong enough for any but the shallower depths. The smaller sizes of flush joint casing listed by the oil supply houses are not strong enough to trust beyond a depth of 1100 or 1200 feet. The flush joint casing used by the diamond drill is made of seamless steel tubing, common sizes being 2-inch (O. D. $2\frac{3}{8}$-inch), 3-inch (O. D. $3\frac{1}{2}$-inch) and 4-inch (O. D. $4\frac{1}{8}$-inch). This casing costs more than other kinds, but the life is very much longer. It hangs free in the hole and can therefore be under-reamed and recovered with greater ease. It does not cause such a reduction in the diameter of the hole as outside coupled casing.

Fewer strings of casing are required because in most formations the diamond drill hole does not cave as readily as the cable tool hole, as the bit makes a smooth cut instead of a jagged break. The only abrasion on the walls is the turning of a line of smooth flush-jointed rods, while in the case of the cable tool outfit the cable is continually whipping the loose particles from the walls. In soft formations the diamond drill can use a fish tail bit with mud-laden fluid and keep the walls plastered with mud. Those familiar with the rotary system of drilling appreciate the great value of this method as a means of preventing cave.

A diamond drill is now in operation in Oregon, and to date has drilled an open hole in formation that has required three strings of casing in nearby churn drill holes. The cave is due to squeezing shale. The squeeze is noticeable in the diamond drill hole when the hole stands for any length of time as be-

twen shifts; but it takes only a few minutes to wash through the cave, and the circulating water keeps the hole open while drilling.

Four holes were recently taken over by a diamond drilling contractor for completion after they had been abandoned by a cable tool drill. One of the holes drilled near Ferndale, Washington, started with a diameter of 18 inches and at a depth of 2100 feet had to be cased with a 4-inch casing. The hole was continued with a small string of tools to 2400 feet. At this point it became necessary to under-ream, but the tools were soon lost and could not be recovered. The diamond drill was then installed. A hole was drilled down alongside of the tools and continued to 3603 feet, finishing with a diameter of 2 7-16 inches. Another well was started by cable tools with a diameter of 15½ inches and was reduced to 4 inches at 2026 feet. The diamond drill completed it to 2826 feet, with a diameter of 2 7-16 inches. Another cable tool hole near Pincher Creek, Alberta, had to use so many strings of casing that it was reduced from 15½ inches to 4 inches in 1500. Again the diamond drill took over the hole and completed it to 3000 feet. The fourth hole was started 10 inches in diameter and had to be changed to a diamond drill hole at 700 feet when it had been reduced to 3½ inches in diameter. In spite of the large number of strings of casing used in these four wells, all four of them had fresh or salt water flowing from the inside casing when taken over by the diamond drill.

These instances are mentioned to illustrate the large number of reductions in casing required by the cable tool drill in comparison with the diamond drill. Along with the saving in weight and cost of the casing comes a saving in the expensive tools for handling the casing, such as tongs, spiders, and many other varieties of casing tools.

Cost of Drilling—Aside from the cost of transportation and casing, the cost of diamond drilling the deeper wildcat wells has been on the whole less than the cost of cable tool drilling. Diamond drilling is not subject to the great variations in costs such as are met in wildcat drilling with cable tools. Drilling with the diamond drill is nearly always cheaper than the other

types of drills in the harder formations. The rotary drill will make the greater progress in very soft formations on account of the great weight of the bit. This system, however, is not suited to wildcat work on account of the poor sample and the danger of drilling through an oil horizon without recognizing it. In shallow wells up to 1000 feet, if transportation is not expensive, the portable churn drill can probably drill at less expense than the diamond drill; although it is expected that the manufacturers will materially improve the efficiency of the diamond drill for this type of work, as they gain more experience.

The principal variable factors determining the actual operating cost per foot of a diamond drill exclusive of handling casing and other extra work, are the rate of progress and the diamond wear. The rate of progress in the diamond drill holes drilled to date varies greatly with conditions. The Panuco-Boston well averaged 35 to 40 feet per day of 24 hours even with the hole full of oil. Another diamond drill recently commenced its first hole in Mexico and to date has drilled a 3⅝-inch hole to a depth of nearly 1200 feet with an average of 66 feet per day of 24 hours, exclusive of time spent in handling and cementing casing, fishing, and other delays. This figure includes all minor delays of less than one tower.

Fishing jobs do not delay the diamond drill as much as the churn drill because the rods give a positive control over the fishing tools that is impossible to attain with a flexible cable. On one hole in Mexico a broken core barrel at the bottom of the hole was fished out with a delay of only seven hours. Less expensive and a less number of fishing tools are kept on hand for diamond drill work.

The other principal factor of diamond drilling cost is the carbon or black diamond wear. A carbon loss of 25 cents per foot is a very high wear for sedimentary formations. In some cases the wear is practically nothing. On the other hand an advertisement of a well known and reliable roller bit for use with the rotary drill cites an instance where the cost in wear of the rollers in certain hard rocks was only $4.10 per foot; the same advertisement gives very much higher costs for other types of rotary bits. $4.10 per foot is probably from

five to ten times the wear that would be incurred in drilling the same rocks with a diamond bit of the same diameter.

GEOLOGICAL INFORMATION

Of equal importance to lower costs, and often of greater importance, is the geological information furnished by the diamond drill cores. To the geologist testing a new locality this information is invaluable. There are a large number of structures that have proved productive only after drilling a number of wells. It is undoubtedly true that many supposedly dry structures might have proved productive if the geologist had had diamond drill cores to assist him in the drilling of additional holes. Those who have seen diamond drill cores from oil or gas sands have been surprised at the unsuspected nature of the information given. In the Panuco-Boston well the occurrence of oil in definite fractures was clearly visible, and in some pieces of core the gas was seen to bubble out of the rock. Frederick Stone, in a paper recently read before the Mining Men's Association of Spokane, describes diamond drill cores from a gas sand drilled by him. These cores showed that in this locality the gas flows through cracks and open crevices in the sand rather than through the pore spaces between the sand grains. The sand was first struck near the end of a run with the core barrel nearly full. When the core was removed from the core barrel a strong odor of gas was noticed. After drilling a few inches on the next run the gas began to bubble up through the circulating water, and on pulling the rods one of the gas seams was noticed in the core. From that point on until the drill passed out of the gas sand these seams were noticed at irregular intervals. In another well, cavities in a limestone were seen to be filled with a heavy black oil.

In the state of Washington a hole was drilled with a diamond drill to reach a rather unusual occurrence of gas in basalt. A 3-inch hole was drilled through a "sand" at 750 feet making 650,000 cu. ft. of gas. The hole was then reamed out to 3½ inches and cased with a 3-inch flush joint casing, and then continued to 2212 feet. Another gas horizon was encountered at 1180 feet. By drilling through a stuffing box they were able to utilize the gas for power. The drill cores gave a great deal

of information on the problem of the unusual occurrence of the gas in the basalt. Churn drillers reported that they got more or less gas in porous layers of the basalt all the way down. The diamond drill proved that the gas came from fractures three to fourteen inches wide, filled with broken material. While certain porous beds above the cracks yielded gas, the full flow did not develop until the seams were reached. The well has not yet penetrated the total thickness of the basalt to determine the original source of the gas.

Under certain conditions it is possible to determine the direction of dip of the formation from diamond drill cores. This is accomplished by lowering into the hole a tube containing a small mass compass floating in hot gelatin and letting it set long enough to allow the gelatin to solidify. At the lower end of the case containing the compass is attached an inverted cup containing wax on which an impression of the irregular surface of the bottom of the hole is made. The impression and the compass test are made at the same time. Water channels cut in the compass case permit the washing of the hole clear of all cave before taking the impression. After removing the impression cup and the compass and marking the north point on the wax, a short piece of core is drilled and removed from the bottom of the hole. By orienting the core so that its upper surface coincides with its wax cast it is possible to project the north point on to the core, and thus determine the direction of the dip of the bedding shown in the core. Corrections for the deviation of the hole from the perpendicular can be made by using a glass tube containing hydrofluoric acid in connection with the compass.

It is difficult to estimate the scope and value of the geological information that can be derived from an extensive use of the diamond drill. Geologists familiar with the methods of taking core with the rotary drill can appreciate the advantages that can be gained from a complete sample wherever desired from the surface to the bottom of the hole. Difficulties of correlation can be reduced to a minimum because the log of the well consists not only of the driller's interpretation of the formations, but also of a physical record showing to within a fraction of a foot every change in character. Fossils, porosity,

saturation, fracturing, and other geological phenomena are studied from a scientific point of view with the aid of the diamond drill. The development of the lease depends to such an extent upon these details of subsurface geology that every lease should have diamond drill cores through the oil sand from at least one or two holes.

OTHER ADVANTAGES

Other advantages of the diamond drill besides the above mentioned advantages of lower costs in certain cases and more reliable geological information have been described in other articles[2]. These advantages include the greater ease with which oil or gas under high pressure can be tapped, the greater certainty that the hole will reach the desired depth, and the ability to use the drill as a means of completing holes that have been started by other methods but for various reasons cannot be completed with the original outfit. Illustrations of the latter case have been cited above, where too many strings of casing necessitated abandoning the hole with the cable tools, but where the diamond drill easily continued the hole. In 1919 a standard hole was drilled in Choctaw County, Oklahoma, to a depth of 2200 feet where quartzite was encountered. The progress became too expensive, so a diamond drill was installed and the hole completed with little difficulty to a depth of 4970 feet, with an open hole from 2200 feet to the bottom.

Another common use of the diamond drill is in mapping gelogical structure by drilling shallow holes to certain key beds. Work of this kind is being carried on in Oklahoma, Kansas, Texas, Illinois, California, and other localities. Such work

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[2]Edson, F. A., Use of the diamond drill in oil fields, Oil & Gas Jour., vol. 19, No. 30, pp. 76-79, Dec. 24, 1920; Drilling oil wells with the diamond drill, Bull., A. A. P. G., Vol. 5, pp 386-393, May-June, 1912; Diamond drilling for production, A. A. P. G., March meeting, 1922.

Danford, M. O., The diamond drill as a wildcat aid, Pet. Age, Vol. 7, pp. 73-74, Oct. 1920.

Mitchell, J. S., Prospecting for oil with the diamond drill, Eng. & Min. Jour., Vol. 113, pp. 18-19, Jan. 7, 1922.

Elledge, Geo. A., The diamond drill in oil field practise, Oil & Gas Jour., Vol. 20, p. 82, Dec. 23, 1921.

Fay, Albert H., The diamond drill as an aid to oil prospecting, Eng. & Min. Jour., Vol. 110, pp. 1133-1134, Dec. 11, 1920; reprinted in Oil & Gas Jour., Vol. 19, p. 88, Jan. 7, 1921.

is usually done with a light portable gasoline outfit and the cost per foot is very low.

OBJECTIONS TO THE DIAMOND DRILL

Certain objections have been raised to the use of the diamond drill in oil work, some of them based on fact, and others on a misconception of the nature of diamond drill work. In the first place it is stated by some that the circulating fluid loaded with the cuttings made by the face of the bit will seal off oil and gas sands. The experience to date in the few diamond drill holes that have penetrated oil and gas sands has proved quite the contrary, the oil flowing freely as in Mexico, and the gas flowing in considerable volume as in the hole drilled in basalt in Washington. If the gas is not sealed off in such a case, it will certainly not be sealed off when it occurs under greater pressure. Moreover in drilling an oil sand, the cuttings are sand, not mud, and therefore should have little if any effect on the flow of oil or gas. In any case cores would present definite evidence of the presence of oil and to some extent that of gas. It is generally recognized by petroleum engineers that a virgin oil sand will usually take little water and practically no mud.[3]

In the second place it is thought by some that a hole drilled with a diamond drill hole is too small, even for a test well. It must be remembered in this conection that the great majority of test wells are dry, and therefore the prime consideration in drilling them is the *most information for the least expense.* Diamond drills can be purchased capable of drilling 4-inch holes 3500 feet and deeper. Since the core shows whether the sands contain oil or not and also shows the porosity, extent of fracturing, and other features, this information alone should suffice. Even for the sake of argument if it is necessary to drill a larger diameter well at the same location, the cost of the original diamond drill hole is a worth while investment from the standpoint of the geological information secured and the assurance of the presence of oil in quantities to warrant drilling the larger holes. But as a matter of fact there is no reason for presuming that the diamond drill hole is not large enough

[3]Swigart, T. E., and Schwarzenbek, F. X., Petroleum Engineering in the Hewitt Oil Field, U. S. Bureau of Mines in cooperation with the State of Oklahoma and the Ardmore Chamber of Commerce, p. 61, 1921.

for production. The Panuco-Boston well flowed 1200 bbls. per day from a $3\frac{5}{8}$-inch hole. Even if the well must be pumped, a $3\frac{5}{8}$ or $3\frac{3}{4}$-inch hole will admit a 3-inch flush joint casing, which in turn will take a 2-inch oil well tubing and working barrel. In deeper holes, say from 3500 to 5000 feet it may be necessary to reduce the diameter to $2\frac{3}{4}$ inches. This hole can be cased with 2-inch flush joint casing which will admit $1\frac{1}{2}$-inch flush joint tubing and a special $1\frac{1}{8}$-inch flush joint working barrel. This working barrel may be smaller than desired, but nevertheless the well will be a producer if oil is found in commercial quantities.

There is no necessity, however, of maintaining this small-sized hole. If the last string of casing is not permanently cemented the diamond drill hole may be reamed so as to increase the diameter from 30 to 50 per cent, permitting the use of a larger pump barrel and tubing. It is possible to ream that part of the hole through the producing horizon still larger with an expansion under-reamer, and thus allow greater seapage and more reservoir space around the barrel.

The Federal leasing regulations specify that a six inch hole must be drilled on government leases. This has been a deterring factor operating against diamond drilling in the Rocky Mountain region and Alaska where diamond drilling would save a great expense in transportation. In this connection the following letter written from the office of the Department of the Interior is of interest in showing that the regulations are not to be arbitrarily applied in all cases, and that under certain conditions the Department may see fit to allow a hole of smaller diameter than six inches:

DEPARTMENT OF THE INTERIOR
WASHINGTON

Mr. Dan Sutherland, Feb. 11, 1922.
Alaskan Delegate,
House of Representatives,
Washington, D. C.

Mr. Dear Mr. Sutherland:—

Referring to the letter from Lynch Brothers dated Jany. 9th, 1922, regarding the use of diamond core drilling in Alaska on Government lands;

The regulations governing prospect work upon Government lands provide that within one year (3 yrs. in Alaska) from a certain date the permittee must drill one or more wells not less than 6 inches in diameter

to a depth of at least 500 feet each, unless valuable deposits of oil and gas are encountered sooner.

It does not seem advisable to change the regulations reducing the diameter of the hole in prospect wells, but I appreciate that there are many cases when diamond drill work would be perfectly satisfactory in order to test out land. It is my belief that in certain cases the Secretary of the Interior will be willing to waive the requirement as to the diameter of the hole provided of course that he is satisfied the work will be carried on in a workmanlike manner and for the purposes of actually testing out the area. Obviously each case must be handled separately and it would be my suggestion for any one wishing to sink diamond core drill holes to meet the requirements of the permit, that they petition the Secretary of the Interior to be granted permission to do so.

Very truly yours,
E. C. FINNEY,
Acting Secretary.

FUTURE FIELD OF USEFULNESS

The extent to which the diamond drill will eventually be used in oil exploration cannot be predicted. A limited field of usefulness is granted by all, but some are hesitant to predict a very wide application without further proof of its value. The proof of its value must come with actual use. Practical results have been cited in this paper which go a long way towards proving its usefulness. Further evidence is desired in different fields; to obtain this evidence someone must be the pioneer. The manufacturers are open minded and willing to cooperate most heartily in the work of adapting the diamond drill to the special conditions and the new demands of oil drilling. Improvements have already been made and more are going to be made. A special oil saver has been designed to permit drilling wells into oil and gas sands under high pressure. One of the manufacturers has designed a complete new drill specially adapted for oil work with double hydraulic feed cylinders of thirty-inch stroke, a sand reel, and a two-cylinder steam engine all in one self-contained unit. Other improvements will follow with increased experience. It is probably safe to predict that the diamond drill will in a short time become the principal drill for wildcat holes. It may not replace to any appreciable extent the cable tool or rotary drill in most proven fields, but will undoubtedly find a wide application as a supplementary device for obtaining geological information to aid in the scientific development of a field.

DISCUSSION

L. E. Trout: In using the diamond drill in producing fields which have a number of horizons producing gas with heavy pressures, say from 400 to 1000 pounds to the square inch, is it possible to mud off these sands successfully or must a new string of casing be set in each case in order to reach a deeper oil producing stratum?

F. A. Edson: Any sand which can be mudded off by the rotary can be mudded off in the same way by the diamond drill, for the diamond drill can use the same fluid as the rotary. In case the gas pressure is greater than the hydrostatic pressure of the fluid in the hole the California system of mudding under pressure can be used successfully. In any event the diamond drill is under no greater handicap than either of the other methods.

John L. Rich: It seems to me that we as Petroleum Geologists should do all that is possible to further the introduction of diamond drilling because the information to be obtained from cores promises to solve many of the scientific problems of petroleum geology which cannot be solved on the basis of the data obtained from the cuttings of the churn drill. Many of these problems have the greatest practical interest. Among others may be mentioned the problem of the so called dry sands of the Appalachian and Kansas fields, and the problem of the significance of fractures as oil reservoirs. The value of cores in settling problems of stratigraphy and correlation is of course obvious.

David White: The increased interest on the part of oil geologists and of the companies in prospecting with the core drill has a very favorable bearing on the search for potash in West Texas long carried on by the U. S. Geological Survey in cooperation with the Texas University Bureau of Economic Geology and Technology. As most of you know, the logs of wells and analyses of cuttings from several of the wells drilled in the region embracing the southern end of the Staked Plains indicate the probable presence of potash in the form of polyhalite in commercial amounts. Nevertheless the exact thickness and the degree of purity of the deposits can not be satisfactorily determined until cores are cut through the potash-bearing zones, which are now known to be rather numerous. Accordingly it is greatly hoped that those oil geologists who have to advise companies regarding drilling in the southern portion of the region of salt deposition, embracing an area of about 125 miles east and west and 75 miles north and south, as shown on a map published in a paper by myself in April by the A. I. M. & M. E., will arrange so far as practicable for cutting cores through the enormously thick salines underlying portions of this region. At least, arrangements should be made for frequent bailing with saving of cuttings and possibly for the use of saturated brines where the churn drill is employed.

John R. Suman: With reference to the use of diamond drill equip-

ment in territory where conditions are similar to those in the fields of Southern Mexico I would offer the following criticism. I have been reliably informed by competent engineers working in the fields of Southern Mexico (Amatlan, Zacamixtle, Toteco, etc) that the gas pressures encountered are greater than the pressure of a column of mud-laden fluid of a height equal to the depth of the hole. For this reason all wells drilled in this territory with rotary drilling equipment have given more or less trouble and some very serious and disastrous accidents have arisen from these attempts to drill into the lime with machinery of this type. It is impossible, with the equipment now in use, to prevent these blowouts and once they start it is impossible to bring the well under control until a vast amount of damage has been done. Operations being carried on with a diamond drilling outfit would be even more susceptible to these troubles than the standard rotary drilling equipment owing to the fact that the ordinary rotary drills use a much heavier mud than the diamond drilling outfit. Furthermore, a standard rotary drilling outfit usually has better tools and appliances at hand for combatting blowout evils than the ordinary diamond drilling outfit.

With reference to the matter of taking cores it might be of interest to those members of the Association who are not up-to-date with present practice in the Gulf Coast fields to know that some very fine work is being done down there in the taking of cores in the drilling of wells with the standard rotary drilling equipment. The taking of cores, both in hard and soft formations, has been developed to the point where almost all the drillers are adept at the work and cores are taken with little or no trouble from wells up to 5000 feet deep. All the larger companies are coreing very extensively in their drilling operations and some interesting information as to the character of the producing formations is being obtained. These cores not only show the extent and general character of the producing sands but fossils are being found both microscopic (foraminifera) and megascopic. By the use of these fossils it is possible to correlate the sands as to age in a much more satisfactory manner than has been possible heretofore. The coring devices used in this work have also been perfected to a very high degree. One ingenious operator has perfected a core-barrel which remains absolutely closed until it gets to the bottom of the hole and starts to rotate. It also closes immediately when the driller starts to remove the drill stem thus making it possible to get cores of the very softest sands and muds. This is quite an improvement over the basket-type of core barrel commonly used which has to be rotated with the full weight of the drill stem on it in order to effect closure. This rotating under pressure generates an enormous amount of heat which quite often melts the core into a slag.

It is my impression that in driling in the soft and caving formations of the Gulf Coastal fields diamond core drilling has very little to offer by way of improvement over the standard rotary drilling methods now in use by the better class of operators.

THE PETROLEUM GEOLOGY OF A PART OF THE WESTERN PEACE RIVER DISTRICT, BRITISH COLUMBIA

BY EDMUND M. SPIEKER

INTRODUCTION

The attention of those interested in the petroleum resources of North America has in recent years been turned with some keenness of anticipation towards the belt of moderately folded rocks lying between the Canadian Rocky Mountains and the plains. Between the international boundary, at latitude 49° N., and the northern boundary of British Columbia, at latitude 60° N., lies a strip of territory, fronting the Rocky Mountains, that is underlain by a succesion of Cretaceous rocks which may somewhere contain commercially valuable accumulations of petroleum. The stratigraphic section is favorable, good structure is plentiful, and a few scattered seepages indicate the presence of petroleum at least locally. The inaccessibility of most of the area has held back development, but in recent years a small amount of geologic work has been done, and drilling has been started at two accessible localities. By far most of the area is a wilderness into which none but the trapper and occasional explorer has penetrated.

During the summer of 1920 the writer, assisted by W. R. Smith, examined in reconnaissance a part of the belt in northeastern British Columbia south of Peace River, and this paper is intended to present briefly the results obtained. The work was done for the Department of Lands of the provincial government of British Columbia, and a report was published as a serial pamphlet of that department in 1921, but that publication does not normally find its way to the geologic public, and the writer has prepared this paper in order that those interested in the region may have the benefit of his observations.

The writer wishes to express acknowledgment to Dr. F. H. McLearn, of the Geological Survey of Canada, for advice and

Introduced by K. C. Heald.

criticism given in the field and office; to Professor Edward W. Berry, of the John Hopkins University, for the determination of fossil plants and for general criticism; to Dr. T. W. Stanton, of the United States Geological Survey, for advice concerning the invertebrates collected, and to the Department of Lands of British Columbia for permission to publish this paper.

Beyond those areas directly adjacent to surveyed land-lines no mapping of much worth had been done in the region, and the accompanying map is largely based on pace traverses carried along all of the routes taken by the writer's party.

LOCATION AND GENERAL CHARACTER OF THE REGION

The region described in this report lies to the south of Peace River, extending as a belt 10 to 40 miles wide from Hudson Hope southeasterly to Murray River at the mouth of Flat Creek. This area forms physiographically a transition zone between the more abrupt foot-hills and the gently rolling plains; the topography is varied, and in places sharply sloped hills break the rolling nature of the terrane, but as a whole the belt is decidedly less precipitous than the foothills.

The region is drained by Peace River and its tributaries. The portion drained by small direct tributaries of the Peace extends from Hudson Hope to the divide north of Moberly Lake. Adjoining this to the south is a belt occupied by Moberly River and its tributaries, which is about 10 miles wide and extends the width of the belt in an east-west direction. The major portion of the area is drained by the Pine River system, the three main branches of which have cut deep vallys across it.

Peace River occupies a valley about 800 feet deep, which in the vicinity of Hudson Hope is from 2 to 3 miles wide. The upper levels of land adjacent to the valley are more or less flat-lying, but 7 miles to the south hills break the evenness of the plateau, and from the general neighborhood of Moberly Lake southeastward over the entire area the topography is broken by hills and the deep valleys of the Pine River drainage.

The valley of Moberly River, which is occupied south of Hudson Hope by Moberly Lake, is from 1 to 2½ miles wide. In the region studied its valley is U-shaped, with many flats

and a meandering stream-bed. It offers no serious difficulty to travel; roads might be cut along it at no great expense.

Pine River flows from Falls Creek to the mouth of Wabi Creek in a deep, U-shaped valley which was undoubtedly the the pre-glacial course of the stream. Below Centurian Creek the present bed of the river is post-glacial, the extensive morainic deposits threabout having deflected its waters southeastward to cut the existing V-shaped gorge through the St. John shales. The old course of the Pine is now occupied by Centurian Creek; it is a broad valley filled with glacial material, in which are many kettles and lakes of glacial origin, and it is clearly discernible from the hills west of Centurian Creek as the course formerly followed by the Pine directly northeastward to the Peace. At the Middle Forks the Pine enters the pre-glacial course of Sukunka River.

Sukunka River is the central member of the Pine River system. It is somewhat larger in volume of water than Pine River. Its valley varies in width from 1 to 3 miles in its lower part and does not narrow appreciably as far as can be seen from the hills at the mouth of Burnt River. For a distance of about 22 miles from its mouth the valley is heavily forested with poplar, willow, and spruce. Above this stretch the timber has been burned, leaving the country bare and open as far as the bend above the mouth of Burnt River.

Murray (East Pine) River is the eastermost and largest of the three main branches of Pine River. Its valley differs somewhat from those of the Sukunka and Pine. Physiographically it is infantile, having long stretches of V-shaped channel, with almost continuous cut-banks of shale and sandstone forming its sides, and in places the stream flows in a true box canyon. The Murray presents a profusion of rock-exposures at the river's edge throughout its length in the area, whereas the other rivers named, occupying more mature valleys, show few cut-banks and expose the more resistant beds only in the upper reaches of their valley-sides. The Murray Valley is heavily timbered, but the timber is small and has accordingly no present commercial value.

The two larger lakes in the area, Moberly Lake and Gwillim Lake, are of common origin, each having ben formed through the damming of its parent stream by glacial material. In each case the localization of the morainic material was undoubtedly determined by the presence at the surface of the resistant sandstones of the Dunvegan formation. The major parts of these two lakes, and of Moose Lake as well occupy beds cut in the St. John shale, but at the east ends of the lakes the overlying Dunvegan formation is brought to water-level by east dips, and its presence there undoubtedly determined the placing of the dams which caused the lakes. It is interesting that the geologic conditions surrounding these lakes are identical.

The entire area is generally well forested with young spruce, pine, poplar, willow, and alder. Localities which are not largely forest are rare. As a rule the northern banks of the rivers have less vegetation, particularly of the forest type, than the southern banks. The dense undergrowth in the forest, together with scattered areas of fallen timber and muskeg, make travel in this country very difficult except on those trails which are kept clear by the Indians for their hunting and trapping. The geologist who plans to work in northwest Canada should be prepared to face these obstacles, and in addition should be willing to endure unparalleled clouds of mosquitoes, black flies, and "bulldog" or horse flies.

With the exception of a few localities on Pine River, there is little or no timber of commercial value in the area. Above Peavine Flat on Pine River are flats on which spruce as large as 30 inches in diameter is growing. Elsewhere, with the possible exception of a small area on the divide between Marten Creek and Rocky Mountain Lake, the writer observed no timber of commercial value.

STRATIGRAPHY

The formations exposed in the region here described range in age from Triassic to Upper Cretaceous. A general review of the entire succession is given in the following table of formations.

Table of Formations

System	Group	Formation	Character	Thickness (in feet)
Upper Cretaceous		Sukunka member	Coarse subareal sandstone, hardened calcareous muds, green shale, lignite	1,000+
	Colorado	Dunvegan	Massive to thin-bedded sandstone, varying in origin from littoral to subaereal, with some shale and few thin seams of lignite.	1,000+
		St. John	Black marine shale, usually arenaceous, with intercalated sandstone and marine sandstone locally	1,400-2,200
Lower Cretaceous	Kootenay	Bullhead Mountain	Hard green-grey conglomerate, coarse-grained, massive sandstone and shale with beds of high-grade coal	1,500-3,000
Jurassic (?)		Pine River	Blue-black marine shale with intercalated limestone and some sandstone	300+ (base not exposed)
Triassic	Upper Triassic	Schooler Creek	Purple and grey limestone. and fine-grained sanstone; limestone vesicular near top.	2600+

The preliminary results of work by F. H. McLearn on Peace and Smoky Rivers, where the whole section is exposed, will be found in Part C of the Summary Reports of the Geological Survey of Canada for 1917 and 1918.

Triassic—Rocks of Triassic age do not outcrop in the area here described, but inasmuch as they would probably be penetrated by a borehole on the Pine River anticline, some mention of such information as exists concerning them is pertinent.

On Peace River, above the Rock Mountain portage, McLearn[1] has found the Triassic series to consist of dark-purple lime-

[1]McLearn, F. H., Mosozoic of Upper Peace River, B. C., Geol. Surv. Can. Summary Rept. Part B, 1920, pp. 2B, 3B.

stones and hardened, fine-grained sandstones with *Pseudomonotis subcircularis* Gabb, and many ammonites. These beds are probably all of marine origin. The sandstone of the Peace

Plate I.

River section is firmly cemented with calcium carbonate, and its general appearance does not indicate that it might make good reservoir rock. However, in the area here considered the

beds have undergone less metamorphism than on the Peace, and the sandstones may be more porous.

Pine River Formation.—This formation is the lowest of the series exposed within the area examined. It occurs at the surface on the crest of the Pine River anticline, being exposed in the narrow valley of Crassier Creek for a distance of about 4 miles above its mouth. It consists chiefly of firm blue-black clay shale, the lowest observable beds of which are remarkably pure, being almost entirely free from sand and presenting the appearance of a hardened, uncontaminated black clay. In this respect it differs from most other marine black shales of the general region, which are almost uniformly sandy. Interspersed with the shale are bands of limestone and sandstone in thicknesses from a few inches up to 20 feet or more; the limestone is very compact and hard, steel-grey on fresh fracture, and, varying with changes in purity, weathers into shapes ranging from angular to gnarled or rounded in outline. The color of its weathered surface is greyish-yellow. No fossils were found in the limestone at any of the exposures visited by the writer.

The section of the Pine River formation exposed in Pass Creek is as follows:

Section of the Pine River formation in Pass Creek

Character of Beds	Thickness (in Feet)
Sandstone of Bullhead Mountain formation.	200
Concealed (shale?).	20-30
Limestone, hard, grey, siliceous.	10
Shale, blue-black, marine, pure, in which are intercalated bands of limestone 8 inches to a foot thick separated uniformly by about 4 feet of shale.	65
Limestone, massive, hard, blue-grey on fracture, weathers dirty yellow, forms cliff.	20
Shale, black, hard, hackly in large proportion, marine.	40
Limestone, weathers into gnarled shapes, blue-grey on fracture.	3
Sandstone and limestone alternating, layers prominent, weathers into flat surface.	3
Shale of same composition as others, but breaking to angular fragments with more or less plane surfaces.	3
Limestone, very siliceous, hard, weathers into angular surface of yelow-grey colour; is steel-grey on fresh fracture.	5-6
Shale, black, hard, hackly.	2¾
Limestone, with 6-inch median parting of shale; hard, steel-grey on fresh fracture, appears pure, weathers yellowish-grey.	5
Shale, blue-black, firm, pure, hackly in large proportion, contains very few fossils.	100

The upper part only of the formation is exposed, and an estimate of its thickness is impossible. It was planned to examine the upper valley of Moberly River in a search for more extensive exposures, but field-work was stopped by unusual weather before this could be begun. Information concerning the downward extent of this shale, therefore, and its relation to the Triassic limestone, is not available. McLearn[2] reports as concealed about 1,000 feet of strata between the uppermost Triassic and the lowermost Bullhead Mountain beds on Peace River, and it is probable that the Pine River formation is represented in that interval.

Prior to the writer's work the existence of the Pine River formation was unknown. Its age is not certain; three fossils, a species each of *Pinna, Pecten,* and *Lima,* indicate the possibility that the beds are Jurassic in age, according to Dr. T. W. Stanton and Dr. J. B. Reeside of the United States Geological Survey, but the evidence is not good enough to warrant a definite statement.

Bullhead Mountain Formation—The section west of Hudson Hope on Peace River discloses beneath the St. John shales a thick series of coarse sandstone and shale of continental origin which have been described by McLearn[3] as the Bullhead Mountain formation. On Peace River the upper part of the formation consists of sandstone and shale, with several beds of high-grade coal, and the lower part consists of massive, coarse-grained, cross-bedded sandstone. The total thickness there is about 3,000 feet.

The formation is exposed on Pine River east of Crassier Creek, where the upturning of the series brings it high into the valley sides on the east flank of the Pine River anticline, and at the mouth of Commotion Creek, where the contact with the overlying St. John shale is approximately 300 feet above the level of Pine River on the crest of the Commotion Creek fold. At the latter locality the upper 200 feet of the formation are well exposed in the canyon of Commotion Creek.

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[2]Op. cit., p. 26.
[3]McLearn, F. H.; Peace River Section, Geol. Surv. Can., Summ, Rept., 1917, Pt. C, p. 16.

The upper member of the Bullhead Mountain formation consists of about 130 feet of extremely hard, resistant conglomerate, the pebbles of which are almost uniformly 1/8 to 1/4 inch in diameter, and which consist of flint, chert, and quartz. They are very well sorted, and are firmly bound by a silica cement. A green chert, which appears to have been stained by glauconite, is prominent as a rule, and inasmuch as it does not exist in any of the clastic rocks above the Bullhead Mountain, it is interesting as a means of identification of the rock, as well as an index to changes in the continental mass to the west as a result of whose disintegration the Cretaceous clastic rocks were formed.

The conglomerate is characteristic in appearance, its distinct mineral content and habit making it lithologically the most easily recognized of any of the Cretaceous beds of the region. Pebbles and small boulders of it are found in all of the larger stream-beds of the area, and although it is clear in some places that they have been transported there by glacial agents, their widespread occurrence gives evidence of the great lateral extent of the formation.

Below the conglomerate is sandstone which decreases gradually in hardness for a vertical distance of 600 feet. Below this sandstone is another massive bed which was seen at a distance in the Upper Pine Valley; this may also be conglomerate. Below that bed less massive sandstone and possibly shale occupy the remaining 600 feet to the top of the Pine River formation. The entire thickness of the formation is contained in the hill east of Crassier Creek and north of Pine River, but none of it is exposed save the massive members mentioned, the remainder being covered by the soil and the dense sub-arctic vegetation.

St. John Fomation.—The Bullhead Mountain beds are overlain by the St. John formation, which consists of 1,400 to 2,200 feet of blue-black to grey shale with intercalated sandstone members. On Peace River the formation is divisible into three members—an upper shale member 1,300 feet thick, a sandstone 80 feet thick, and a lower shale member 800 feet thick. The upper member consists of typical marine black shales, with little or no sandstone, but the lower member contains many

small thicknesses of sandstone. The Peace River section has been described by F. H. McLearn[4].

The St. John shale is distributed in outcrop over the entire area. It forms the valley sides of Peace River in the vicinity of Hudson Hope. To the south, in the hills north of Moberly Lake, the overlying Dunvegan sandstone forms the surface, but in the valley of Moberly River the shale reappears. It outcrops in the valleys of Pine, Sukunka (above Marten Creek), and the Murray rivers; on Tuskoola and Table mountains; and in the area southwest of Gwillim Lake, the shale forming the lower valley sides as a rule, and the Dunvegan sandstone capping the ridges. In the area south of Peace River the lower part of the formation contains many irregular sandstone members, and the differentiation of the middle member of the Peace section is not clear.

All known exposures which reveal the contact between the St. John shales and the Dunvegan formation show a gradual transition from beds of distinctly marine origin to continental sandstone and shale with lignite and plant impressions. In Paquette Creek, on the north shore of Moberly Lake, the following section was measured at the top of the St. John formation:

Section on Paquette Creek

Formation	Character	Thickness (in feet)
Dunvegan	Sandstone, fine-grained at bottom, increasing in coarseness of grain to top	200
	Sandstone and shale, predominantly sandstone	22
	Shale and sandstone, predominantly shale	16
Transition Zone	Shale, black, sandy, with concretions of sandstone and ironstone	18
	Sandstone, massive, fine-grained, grey	1
	Shale as above	20
	Sandstone, platy, with shale intercalations	1
St. John	Shale, black, sandy in places, with limestone concretions and bits of comminuted plant remains	80
	Creek-bottom.	

A transition similar to this was noted wherever the contact

[4]McLearn, F. H.; Peace River Section, Geol. Surv. Can., Summ. Rept., 1917, Pt. C.

between the two formations was observed. The upper part of the formation is exposed in the vicinity of Moberly Lake, in the narrow valleys of the creeks tributary to the lake, and in the lower valley of Miller Creek. There it consists of marine shales, arenaceous as a rule, varying in character from fissile to hackly, and locally calcareous. On Pine River the upper shale is not commonly exposed, the hillsides being covered with vegetation, but such occurrences as were noted reveal at least 500 feet of shale containing no important sandstone members. In the area southeast of the Middle Fork the upper shale of the formation is entirely similar.

The lower part of the formation consists of a series of alternating shale and sandstone at all exposures seen by the writer. A typical section of this part of the formation is exposed in the valley of Commotion Creek above the falls, as follows:

Section Measured on Commotion Creek.

Formation	Character	Thickness (in feet)
St. John	Sandstone, massive, yellow-grey	70
	Shale, black, marine, thin-bedded, arenaceous, with even lines of ironstone concretions and thin bands of sandstone	550
	Sandstone, massive, medium-grained	25
	Sandstone, soft, friable, with carbonaceous matter	2
	Shale, black, sandy	3
	Lignite-seam	1
	Shale, sandy, with bands of carbonaceous matter approaching lignite in composition	35
	Sandstone, continental in origin, soft, friable, containing carbonaceous matter and leaf impressions	20
Bullhead Mountain	Conglomerates of Bullhead Mountain formation	130

On the northern escarpment of Tuskoola Mountain is exposed a series of shales and sandstones which have been assigned to the St. John and Dunvegan formations. The base of the Dunvegan beds is at an elevation of about 4500 feet on Tuskoola Mountain, and at the Middle Forks of Pine River its elevation is about 2000 feet. The identification of these beds

was made on the basis of marine fossils collected on Tuskoola Mountain, and if it is correct, either a fault or a sharp monoclinal fold exists in the intervening area, which must be examined before the identity of the beds in Tuskoola Mountain may be considered certain. Circumstances prevented such an examination during the course of this work. The presence of a fault is further suggested by the occurrence in Dickebusch Creek, a tributary of Sukunka River, of float bearing species of Kootenai plants common in the Bullhead Mountain formation. A fault large enough to account for the difference in elevation of the beds in question would bring the Bullhead Mountain beds to the surface east of Sukunka River.

Fossils collected in the vicinity of the mouth of Fish Creek on Murray River support the areal determination that the shale there is coeval with the Tuskoola Mountain shale. In the canyon of Gordon Creek there is no marine sandstone at the top of the St. John, the conglomerate and oyster-beds of the Tuskoola Mountain section being followed directly in downward succession by pure marine shale. The shale of Gordon Creek is traceable along the valleys of Murray River and Fish Creek to Gwillim Lake, and thence to the southeasternmost part of the area, on Flat Creek. The essential characteristics of the formation are constant over this area.

The thickness of the St. John formation is about 1,400 feet on Pine River. In the valley of Murray River between the crest of the Canyon anticline and the mouth of Wolverine River, where the only other nearly complete section of the formation is exposed, 1,500 feet were measured without reaching the base of the shale. There is thus a decrease in thickness from the Peace southward and westward; this is without doubt due to a westward replacement of the upper shale horizons by the continental beds of the Dunvegan formation.

Dunvegan Formation.—Directly overlying the marine shales of the St. John formation is a series of sandstones and continental shales named by Dawson the Dunvegan formation and studied recently by McLearn[5]. These beds, which for the most

[5]McLearn, F. H.: Peace River Section, Geol. Surv. Can., Summ. Rept, 1917, Pt. C, p. 18. Also McLearn, F. H.: Cretaceous, Lower Smoky River, Geol. Surv. Can., Summ. Rept., 1918, Pt. C.

part are moderately resistant to weathering agencies, form the main body of most of the hills in the areas. They extend in surface outcrop along the belt of moderate folding for the entire length of the region under consideration, and form the upper reaches of all the prominent hills save those at the edge of the disturbed belt, where the older formations have been brought up by the intense folding.

In the vicinity of Moberly Lake the lower beds of the Dunvegan formation form the upper reaches of the range of hills extending southeasterly from Hudson Hope to Pine River. These beds are more or less heterogeneous in composition and origin. At the contact with the underlying St. John formation there is a true gradation between marine shale and continental sandstone, the marine beds below passing conformably into brackish and fresh-water argillaceous sandstones, with fresh-water limestone in places. On the south shore of Moberly Lake two thin beds of lignite occur 45 and 65 feet above the base of the formation. Occasional lentils of hard limestone, as well as some sandy layers, contain a few fresh-water gastropods and pelecypods. These beds are succeeded above by subaerial sandstones, for the most part cross-grained, massive, and cross-bedded, containing leaf fragments whose disposition gives clear evidence of non-aqueous distribution of the materials.

This series of sandstones, with irregular lateral variation from continental to shore facies, extends in the higher elevations from Moberly Lake to the Middle Forks, where its base is approximately 150 feet above river-level, and a thickness of 600 feet, more or less, is irregularly exposed in the hill north of the fork. From this point south, in the valley of the Sukunka, the southwest dip carries the series under, and at Dickebusch Creek, where the base of the formation is estimated to be at least 1,000 feet beneath the surface, the facies changes from the sandstones typical of the Dunvegan as known to the north to a series of continental green shales, hardened calcareous muds, and grey, platy, cross-bedded, lenticular sandstones with flat nodules of black shale and occasional shaly layers. These beds are undoubtedly continental in origin. They contain seams of carbonaceous material and some low-grade coal.

The complete change in lithologic characteristics presented

by these beds affords reason for their consideration as a separate unit, and to meet the needs of his field terminology the writer called them the Sukunka beds. At present they may perhaps be included with the Dunvegan as an upper member of that formation, but future detailed work may reveal the necessity for their adoption as a separate formational unit. They may represent the westward phase of the Smoky River formation.

The thickness of the Sukunka beds is not known, their upper reaches not having been seen in detail by the writer, but their apparent continuation up Sukunka River from Dickebusch Creek to the synclinal axis beyond Marten Creek shows a thickness estimated at 1,000 feet or more. The valley sides here are well clothed with soil and grassy vegetation, and since the harder, cliff-making members of the series are the only ones which appear, a detailed examination of the beds was not possible.

The Sukunka beds appear also in the canyon of a small creek at the southwest corner of Gwillim Lake. Here they consist of massive sandstone layers 5 to 10 feet thick, granular grey-brown shales 2 to 4 feet thick, thin layers of micaceous grey sandstone breaking to feather-shaped fragments, hard, green-grey shales weathering brown, hackly to fissile, paper-thin black shales in thicknesses up to 2 feet, and thin-bedded sandstones. The beds at this locality are estimated to extend possibly 100 feet higher stratigraphically than the section examined in Dickebusch Creek.

At this locality, as well as in Dickebusch Creek, three species of fossil plants were found. These have been determined by Professor Edward W. Berry, of the Johns Hopkins University, as *Anemia fremonti* Knowlton, *Dryopteris coloradoensis* Knowlton, and *Populus* cf. *elegans* Lesquereux.

Of these the *Anemia* and *Dryopteris* are common in the Fontier formation of the western interior of the United States and the *Populus* is a typical Dakota species. The forms thus present to things which are of interest in the development of stratigraphic knowledge in the Canadian Northwest: (1), evidence additional to that afforded by invertebrate faunas from the Peace River area which points more clearly at each

new discovery to the Colorado age of the beds; and (2) further evidence of an interesting vertical persistence in northwestern North America of certain floras which to the south and elsewhere occur at earlier horizons, and representatives of which are found in Alaska in beds as young as Tertiary in age.

The Dunvegan proper—i. e., the series underlying the Sukunka beds—yielded the following plant species: *Protophyllum lecontianum* Lesquereux, *Platanus latior subintigrefolia* (Lesq.) Knowlton, *Menispermites reniformis* Dawson (?), *Aspidophyllum trilobatum* Lesquereux, *Cycadites unjiga* Dawson, *Platanus* sp., and *Taxodium sp.* The general aspect of this assemblage is Dakota rather than Colorado, and its occurrence in the Dunvegan formation, which has been shown rather definitely to be Colorado in age, presents more evidence of the persistence of many Dakota forms. The *Menispermites* and the *Cycadites* are typical Dunvegan species, the former having been collected by the writer and others in previous work, and the latter having been found by Dawson in his exploration of the Peace River district in 1879. The *Aspidophyllum* is identical with the form described as *Protophyllum* by Dawson.

The Dunvegan formation thickens materially south of the Peace in the region between Hudson Hope and Moose Lake. If the whole series is found to be more or less coeval with the Dunvegan of Peace River, there was a basin in which deposition of sediments was much more rapid than to the north. However, further work may show parts of the thick series to belong to either the St. John or Smoky River periods, or both, and it is not improbable that the Sukunka beds may represent the westward extension of the deposits laid down in early Smoky River time.

GEOLOGY AS APPLIED TO OIL AND GAS

Possible Sources of Petroleum.—First-hand evidence of the presence of petroleum in the Cretaceous of the mountain front is rare. A few scattered seepages have been discovered, but on the whole the actual proof of petroleum in the rocks is not as good as might be desired. In the area here discussed the writer found no seepages or other certain evidence of petroleum.

The nearest known seepages occur about 45 miles east of

the eastern limit of the moderately folded belt, near the town of Rolla, B. C., on Pouce Coupe River. Oil has been found there seeping in small quantities from a sandstone which may be in the St. John formation, and gas-seeps are common in the vicinity. One oil-seep is known about 4 miles north of Peace River, on Moose Creek.

Drilling has recently been started at the Rolla locality, solely on the evidence of the seepage, and early in December, 1921 the well was reported to be down 1900 feet, having encountered a flow of gas estimated at 10,000,000 feet, but no commercial production of petroleum. There is no appreciable fold there.

Seepages of petroleum have been reported variously to exist at many other places in northwest Canada, but thus far few have been actually found.

In the area here described three general parts of the stratigraphic column may be oil-bearing at depth. The Triassic limestone and sandstone may contain oil. The formation is not petroliferous at any known exposure, but all known exposures of it are in the disturbed belt, where metamorphism has taken place. It probably underlies the Pine River anticline at a depth of less than 1,000 feet, and since there is very little evidence of metamorphism there, it is worthy of a test. The Pine River formation, which includes at least 230 feet of black shale, may have been a source of petroleum, but it does not contain much promising reservoir rock. The sandstone in the lower part of the Bullhead Mountain formation would make a good reservoir and lenses of porous sandstone may be present in the Pine River shale east of its exposure, where it is beneath the surface.

The third hopeful part of the column is the lower part of the St. John shale. These beds promise more than any of the lower formations; in a vertical interval of 700 feet measured upward from the base of the formation, there are about 500 feet of black marine shale and 150 feet of interbedded sandstone. The sandstone beds are all porous, and would make good reservoir rock. The underlying conglomerate of the Bullhead Mountain formation is too firmly cemented to be considered as reservoir rock.

STRUCTURE

The geologic structure of the belt fronting the foot-hills of

Northwest Canada consists of a series of moderate undulations of the strata, the crests of the folds lying in the main parallel to the axis of the Rocky Mountain chain, and the continuity of many single structures being remarkable. The folds are nearly all open, and many of them are of dimensions and conformation ideal for the retention of any oil and gas which might have existed in the rocks they embrace beneath the surface.

The region between the western limit of the area and the mountains proper is known geologically as the Disturbed Belt. Within it the rocks have been folded and faulted to high degree, the forces which built up the Rocky Mountains having reacted on them with great intensity. To the east and southeast the effect of these huge forces was absorbed gradually until in the region which now forms the plains the strata underwent no change from their natural horizonal position. The belt considered in this report lies betwen these two extreme areas, and there, although the full strength of the forces had been partially dissipated, enough pressure due to the thrusting penetrated the local rocks to cause ordinarily unbroken flexures of comparatively gentle slope. The structures occur along two or three principal lines and the sharpness of the folding decreases regularly from west to east.

ANTICLINES THAT MAY CONTAIN OIL AND GAS

The major anticlines of the area are shown on the map. Brief remarks on each, taking them up in the order of their distance from Hudson Hope, follow:

Hudson Hope anticline.—The Hudson Hope anticline is a low fold of small extent, and is not by any means as promising a structure as others to the south. It is the most easily accessible fold in the area, however, and on that account has attracted the attention of oil men. Near the crest of the fold where it crosses Peace River the dips are about 2° on both flanks, and about a mile and a half west of the axis there is a structural terrace with a maximum west dip of about 15°. The axial extent of this fold is little known on account of lack of exposures. It is believed to be continuous with a faulted fold exposed in the west fork of Maurice Creek, but it probably dies out to the south.

At the crest of the fold the lower shale member of the St. John formation is exposed, and the strata beneath the surface consist of the remaining 600 to 700 feet of sandy shale and intercalated sandstone of the St. John formation, and the underlying continental sandstone, shale and coal of the Bullhead Mountain formation, at least 3000 feet thick, according to McLearn. The St. John beds, and possibly neighboring sandstones in the Bullhead Mountain formation, may yield oil, but the lower massive sandstone of the Bullhead Mountain offers little promise. The Hudson Hope anticline is hardly pronounced enough to have been thoroughly effective as a reservoir structure, and the comparatively small thickness of hopeful beds beneath it within ordinary drilling depth emphasizes the decision that it is not to be considered with the best anticlines of the region.

Moberly Lake anticline.—The Moberly Lake anticline is clearly visible in the hills south of Moberly Lake, where the massive lower sandstone of the Dunvegan formation stands out in sufficient boldness to display the arch very plainly. It is much better formed for the retention of petroleum than the Hudson Hope fold, having dips of 9° and 5° on its east and west flanks, respectively, and in the valley of Moberly River there are probably 1000 feet of St. John shale and sandstone beneath the surface at its crest. On the south side of the valley it is clearly defined, but to the northwest it appears to decrease in prominence. Southeast of its exposure at Moberly Lake the plateau is heavily covered with glacial drift as far as the middle forks of Pine River, and its presence there is known only indefinitely. It is inferred to exist continuously in this section because of west dips in the valley of Centurian Creek about 4 miles above its mouth—the strata must somewhere arch over to the east, into the broad syncline of the plains—and because of the strong possibility that the Table Mountain anticline, a broad, low structure that crosses the Pine River at Table Mountain, is continuous with it.

Miller Creek anticlines.—The Miller Creek anticlines are next in order of accessibility. The northernmost major fold crosses Miller Creek 4 miles from its mouth, and is about 30 miles by trail from Hudson Hope. On its east flank the dips

are moderate, ranging from 2° to 8°, but the west flank plunges sharply, having a maximum observed dip of 62°, and flexing upward again in an acute syncline whose axis is not farther than one-quarter mile from the crest of the fold. The St. John shales outcrop at the axis of this anticline, and the sandstones in the lower part of that formation are estimated to be about 1,000 feet below the surface on Miller Creek. This anticline is flanked by one to the south which is not so steeply folded, the dips of its flanks averaging about 8°. Beyond are several minor undulations which are not of sufficient prominence to warrant their consideration here.

The conformation of the first anticline is hardly ideal. The second structure is better formed than the first, and if the locality is to be tested it will merit the first attempt; however, it is apparently local in nature and the area of its flanks is small.

The Pine River anticline.—The Pine River anticline, as reference to the map will show, is a pronounced structure. On its east flank the dips attain a maximum of 25° in the hills east of Pass Creek, and decreases gradually in steepness to Peavine Flat, where the beds are horizontally disposed. On the west flank dips as high as 60° occur. The fold is thus distinctly asymmetric, the west flank being the steeper. Its degree of sharpness is certainly ample for the retention of petroleum, and the large areal extent of its flanks and their apparent freedom from excessive metamorphism place it among those structures which are to be classed as hopeful.

The beds beneath it are not definitely known; the lowest beds seen by the writer outcrop at its crest on Crassier Creek, and the nearest exposed section of the lower rocks, on Peace River, does not disclose[6] the beds between the Schooler Creek and Bullhead Mountain formations. It is probable, however, that the uppermost known Triassic beds are within 1000 feet of the surface in the Pine River valley at Pass Creek, and it offers therefore the best site in the area for a test of the lower formations.

[6]McLearn, F. H., Mesozoic of Upper Peace River, B. C., Geol. Surv. Can. Summary Rept. 1920, Part B, p. 36.

The Commotion Creek dome.—The Commotion Creek dome occurs along the same general line of folding as that found on

Miller Creek. Its outlines are exposed in the rude cross cut into the rocks by Pine River, Commotion Creek, and Goodrich Creek, and inspection of the outcrops presented there shows the fold to have a roughly elliptical form, the long axis extending in a direction a few degrees west of north, and the dips being steeper on the north side. The existence of the structure has undoubtedly determined the location of Commotion and Goodrich Creeks; hence its almost perfect quadrisection by the three drainage-channels.

The top of the Bullhead Mountain formation is about 300 feet above the level of Pine River at the apex of the fold, and the underlying section consists accordingly of approximately 1,200 feet of the sandstone, shale, and coal, of the Bullhead Mountain formation, with the Pine River shale and limestone below. The possibility of oil-bearing horizons below the Bullhead Mountain formation, coupled with the dome-like shape of the structure, presents a geologically attractive situation as far as oil and gas are concerned.

The Table Mountain anticline.—This fold may be the extension of the Moberly Lake anticline. Its crest appears to have the usual northwest and southeast direction, and it crosses Pine River near the eastern end of Table Mountain. It is not a pronounced structure; the dips on the east flank are at most 3°, and on the west flank the average dip is approximately the same, although on a structural terrace visible in the eastern end of the hill north of the Middle Forks west dips as high as 10 are measurable over a short distance.

In the Pine River Valley, where a drilling location would be most advisable in the interest of accessibility, depth of worthwhile drilling, and general economy of prospecting, the top of the St. John shales is at least 1,000 feet above river-level. The total thickness of the St. John shales is not known exactly in this locality, but it is not likely to be much different from the 1,400 feet measured on the Pine at Boulder Creek, and the thickness of hopeful strata below the surface is probably not more than 400 feet. Below that lies the 1,500 feet or more of the Bullhead Mountain formation, in the main body of which no oil need be expected. A prediction concerning the possibilities in beds below is not entirely safe; the Pine River shales may be

present at a depth of from 1,900 to 2,200 feet, but since nothing is known as to their lateral persistence to the east it is not possible to make a valuable estimate of the chances in deep drilling on the Table Mountain fold. A borehole on the Boulder Creek dome would yield information which might throw considerable light on this question, and, at all events, if it is desired to test the Pine River formation the Boulder Creek locality far excels any other in point of drilling depth, amount of hard rock to be penetrated, and degree of sureness of the presence of the formation underground.

Remaining folds in southern part of area.—The folds south of Pine River are at present so difficult of access that they will probably not be tested for many years, unless production is obtained at some more accessible locality in the area.

The structure in the Sukunka Valley is synclinal for about 10 miles above its mouth. The first major anticline observable occurs near the mouth of Brush Creek; it is mapped as the Sukunka anticline. Its relation to the other structures of the area is not entirely clear. Its crest probably follows the northwesterly trend of the belt, but this is by no means certain. Extreme irregularities of strike on its flanks make it impossible to define its contour without detailed work involving far more time than that available to the writer, and its inaccessibility discouraged giving it more attention than that possible in reconnaissance. It may form the rim of the wide synclinal basin south of Pine River, and as such may be continuous with the Boulder Creek-Miller Creek fold-line to the north and the Rocky Mountain Lake fold-line to the south.

The conformation of the Sukunka anticline is good, dips on the east flank ranging from 5° to 10° in the vicinity of the crest and on the west flank from 15° to 40°, and the strata beneath the surface on the Sukunka River consist of St. John shale and sandstone to a probable depth of 800 feet.

The longest apparently continuous fold in the area occurs between Rocky Mountain Lake and Flat Creek. Its presence has been observed by the writer at the forks of Flat Creek, 18 miles from Murray River; at the mouth of Flat Creek; on Bullmoose Creek near its mouth and 2 miles up-stream; at the west end of Moose Lake and at the west end of Rocky Mountain

Lake. Although nothing is known of its presence between these localities, their alignment indicates the strong possibility of its continuity. This long fold, which may be called the Flat Creek anticline, is flexed moderately at most of the points which have been observed, and is accordingly worthy of consideration as a possible container of petroleum.

At its exposures in the valleys of Flat Creek, Murray River, and Bullmoose Creek, the fold embraces beneath the surface a small thickness of the St. John shales and the full thickness of the Bullhead Mountain formation. It is likely that the top of the Bullhead Mountain formation is not far beneath the surface in the general vicinity of Murray River, and that accordingly the value of the structure in terms of present knowledge is questionable.

The most favorable localities, geologically considered, on this fold are those at the western ends of Rocky Mountain and Moose Lakes, where the underlying strata consist of nearly the entire thickness of the St. John shale.

About 6 miles below the mouth of Flat Creek a fold, called the Canyon anticline, crosses the valley of Murray River. In degree of flexure it is less pronounced than the Flat Creek fold, which succeeds it to the southwest, but it is clearly defined, the dips on the east flank being in the general neighborhood of 9° and on the west flank between 7° and 15°. It probably dies out to the northwest, and to the southwest its extension is not certain, although a fold which may be integral wit hit occurs in the valley of the East Fork of Flat Creek about 3 miles above the forks of the creek. Its contour on Murray River is favorable to the storing of oil, and inasmuch as the major portion of the St. John shales probably underlies the surface at its crest, it is worthy of note geologically, but it is at present too difficult of access to be considered on economic grounds.

A pronounced fold of almost symmetrical proportion occurs in the hills west of Bullmoose Creek in the vicinity of the trail from Moose Lake to Wolverine River. It is indicated on the map as the Bullmoose Creek anticline. Northwest and southeast of this locality the structure along the line of the fold is much broken up and really forms the outer edge of the Dis-

turbed Belt, but at the locality mentioned a somewhat hurried examination revealed no extreme contortion of the strata. At some point along the crest of the fold and in the general vicinity of the trail mentioned a test would be advisable in the existence of some sort of transportation facility, but the great cost of exploratory drilling at so great a distance from existing lines of freight-travel precludes active interest in the structure for some time to come. It is probable that at least half of the St. John formation underlies the surface at the apex of the fold..

Minor folds.—The flanks of the major structures mentioned above are, in some places where the dip is low, flexed slightly into minor folds of local extent. These smaller structures should not be considered as places for preliminary tests of the region, but inasmuch as certain of them include beneath the surface the most attractive formations of the series, they may be considered briefly.

Several minor undulations occur in the valley of Miller Creek. Their location and degree of flexure are indicated on the map. One north of the main Miller Creek folds includes the major part of the St. John shales beneath its crest, and those to the south include the entire thickness of these shales with part of the overlying Dunvegan formation.

Reversals of dip, indicating a small local "roll" in the structure, occur in 7-Mile Creek, in the Sukunka drainage area. This fold embraces in sub-surface formation the lower half of the Dunvegan formation and the underlying St. John shales, and consequently may merit attention if these formations are found to contain oil.

Another minor fold exists in the narrow valley of Fish Creek near its mouth. This is perhaps the most interesting of the minor folds observed; the section underlying it embodies the most promising part of the St. John shales, and the dips on its flanks near the crest range between 4° and 6°.

TRANSPORTATION

At present the region is accessible via three routes of travel, one from the west and two from the east. The western route, from Fort Gorge via the Giscome Portage, Crooked River, and Parsnip River to the Peace, is a water route, and is preferred

by some prospectors, travellers, and engineers for comparatively light travel. It is not a good route for the transportation of heavy equipment. The routes from the east leave the end of steel on the Edmonton, Dunvegan & British Columbia Railway at Peace River Crossing and Spirit River or Grande Prairie respectively. The first of these is the most used and is the best for the transportation of all classes of freight; it makes use of Peace River, which is navigable by vessels of light draught between Fort Vermillion and Hudson Hope. The season for navigation on the stretch between Peace River Crossing and Hudson Hope includes the months of June, July, and August as a rule, and in some years the large steamer makes the trip in September. Smaller craft ply the river as late as the first formation of ice.

The third route mentioned is a land route. From the railway points of Spirit River and Grande Prairie wagon-trails lead to Pouce Coupe, whence a more or less passable wagon-trail leads to Pine River at the mouth of the Murray, at the eastern edge of the area in question. The trail from Spirit River to Pouce Coupe is not used in summer on account of muskeg; it is a winter trail, and is used chiefly by the farmers of the Pouce Coupe Prairie for the haulage of their grain to the railroad. The road from Grande Prairie to Pouce Coupe is by far the better; it is passable to automobiles in dry weather and is extensively used for freighting into the Pouce Coupe district.

West of Pine River at the mouth of the Murray travel by wagon would involve much road-cutting. A road is supposed to exist as far as Hudson Hope, but it is not used by teams, and it is not likely that a wagon could make the trip without much road-building work.

Within the area travel is nearly all by pack-train in summer and by sleigh in winter. Wagon-roads exist about Hudson Hope and on Lone Prairie, but they are of local importance only, and most of them would not suffice in their present state for the haulage of heavy freight.

The transportation of equipment from the rail head to any of the localities at which drilling might be contemplated would involve the cutting and grading of road if the materials were to be hauled in summer. In winter the frozen rivers offer

roadways to sleighs when the ice is favorable, and the problem of present-day transportation of drilling materials to the region must not be considered without examining the possibilities of winter travel.

Suggestions for exploratory travel.—Travel for purposes of exploration in the Rocky Mountain front region must be by pack train, or, in areas accessible by water, by canoe. Pack travel is the most used, and the geologist who contemplates work in the belt anywhere north of Athabaska River should familiarize himself with the peculiar demands of northern travel. Some very good hints are given in a Handbook of Travel, published by the Harvard University Press.

The trails are not good, as a rule, and travel is necessarily slow. In the particular area described in this paper the main trails are better than elsewhere, and the geologist may travel expeditiously on them with horses. The side excursions necessary to geologic work are best made afoot. In the area adjoining on the southeast, between Flat Creek and Athabaska River, pack travel is much more difficult on account of muskeg and windfall, and the pack train should be in charge of an experienced man.

Experience has shown that the number of horses needed for a stay of five or six weeks in the wilderness, with a carefully selected outfit and stock of provisions, is about one and a half to the man, including saddle animals. It is advisable to take an extra animal. Horses may usually be hired or bought at the chief starting points of expedition, but no geologist should leave Edmonton or Peace River Crossing without first finding out whether animals are available in his territory. The animals can live comfortably on the luxuriant grasses that are almost everywhere plentiful during July, August, and September. it is impossible to carry feed expediently. A packer who knows the location of feeding grounds is worth many hours of valuable time to the party, for the camping places must be chosen with first regard for the needs of the horses. Men who have disregarded this prime consideration have come to grief. The geologist must make up his mind to adapt his work as well as possible on long trips to the routes and stopping places that will allow the horses to thrive.

The equipment should be as light as possible, and should be stripped down to those light things that are absolutely essential. As much dried food as possible should be taken. Tents should be of silk, beds, if possible, of eiderdown. Anything easily breakable will not last long in the average pack. Mosquito bars are absolutely essential; the writer has found a silk tent, with canvas floor and mosquito door, about as good as anything. Citronella preparations may help. Waterproof leather boots are good to have at times, and in wet years they save much discomfort.

It is advisable to have fibre pack boxes, specially built by dealers in sporting goods, for instruments, stationery and other such equipment, and everything that can not stand a wetting should be in waterproof covering. Everyone should always have with him a supply of matches in a waterproof box. Clothes for both cold and temperate weather should be taken. Pack-sacks, with tump-line and forehead straps, for making short trips with supplies on the back, and light bedding are very valuable in case it is necessary to go off for more than a day into country impenetrable by horses. The .22 calibre rifle is the most serviceable of all, except in the big game season, when a .30 U. S. Government '06 is best, and the .303 British or the .32 Winchester Special are good. A .22 pistol is a valuable arm, and carbines, not rifles, are best for pack travel.

A medical chest, containing common remedies and surgical equipment for ordinary accidents, should be included, and some one in the party should familiarize himself with the treatment of ordinary injuries and illness. It is well also to know something about the ordinary diseases of the horse.

A good handbook of medicine[7] will furnish all of the information necessary to cover cases that can be treated away from hospitals. Very serious injury, such as a compound fracture of the thigh, is almost certain to result in death unless the patient can be removed to a hospital within a comparatively short time, and this fact should be uppermost in the mind of the geologist when he is tempted to risk physical injury in a remote place.

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[7]See "Prevention of Disease and Care of the Sick", Miscellaneous Publication No. 17, U. S. Public Health Service.

Ration lists such as those used by Alaskan parties are the best to follow in buying provisions; they have been published in several handbooks on exploring.[8]

The suggestions given above are somewhat bare, and largely unexplained, but the geologist who starts out to work in the north will soon discover the reason for them. They are offered here as a possible help to any who may be called upon to undertake a new experience in travelling the northern wilderness.

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[8]Paige, Sidney: Hayes's Handbook for Field Geologists, p. 15, New York, John Wiley and Sons, 1921.

DISCUSSION

ON DIAMOND DRILLING

In Volume 5, Number 6, page 674, of this Bulletin appeared a discussion by Mr. Charles E. Straub, on the article on Drilling Oil Wells with the Diamond Drill, by Frank A. Edson, which appeared in Volume 5, Number 5 of the Bulletin.

Mr. Straub, while pointing out the desirability of core drilling, cites several drawbacks which he considers will prevent the general use of the diamond drill in oil exploration. The writer has had considerable experience with diamond drilling, both in the various mining districts and in oil work, and believes that the diamond drill can be used to great advantage in certain phases of oil exploration. The objections to which Mr. Straub refers are not now so serious as they perhaps were at the time he made his investigation of core drilling and they present no real obstacle to the use of the diamond drill. During the past two or three years, the manufacturers of diamond drills have given considerable attention to the adaptation of the equipment to oil field work, and much progress has been made.

Diamond drills and equipment are now made to cut holes as large as 8 inches in diameter, and drills of this type, making large holes, are now in successful operation in the oil fields of Mexico. Moreover, these drills can be used to rotate fish-tail bits or other of similar tpe, used in ordinary rotary practice, and by the use of mud-laden fluid, as with a rotary, the diamond drill can be used to penetrate soft, caving formations, which, in older practice, would have been considered entirely unsuited for diamond drilling. Also by the use of the double tube, or floating tube core-barrel, the core is protected from the water action by an inner tube, and cores of small or large diameter even in soft or friable material such as shale, or loosely consolidated sandstone, are successfully taken.

These large diamond drills can also be user in combination with the cable tools outfits. The steam cylinders can be omitted from the diamond drill and the drill driven by sprocket chain connection with a pulley mounted on the band-wheel shaft of the standard rig. The drill can be quickly connected and used when drilling in hard formations, or where it is desired to secure cores. When such work is completed, it can be slid out of the way and churn drilling resumed.

The chief point which the writer wishes to make is that undue objection to diamond drilling has been made on account of the cost of the necessary carbon; the carbon loss in drilling; and the extra labor cost on account of the necessity for expert service in the person of the diamond-setter. Let us consider these points in order:

(1) *Cost of carbon.* The carbon required for the ordinary drilling operation will range in value from $2500 for the smaller sizes of bits, up to $5000 for the big bits referred to above. These figures contemplate enough stones to set two bits, though, as will be pointed out under (3),

this is not really necessary. But even taking $5000 as a representative figure for the purpose, it is at once evident that this is not a large amount compared with the cost of some of the equipment that makes up the ordinary cable-tools or rotary outfit. And much more than this amount may be saved on a single test in a wild-cat region through the lower transportation charges and smaller investment in casing which is made possible through the use of the diamond drill. It should be remembered, also, that this investment is not an outlay to be charged to a single hole, but represents an accessory which can be used over and over in successive holes and still have a readily realized salvage value until the stones have worn to a size too small for efficient use.

(2) *Carbon wear or loss.* Were this as great in the oil fields as in many of the mining districts, it would mean a very serious objection to the use of the diamond drill in oil work. As a matter of fact, however, the actual carbon wear in the sedimentary formations of most of the oil fields is extremely small. On one contract in northern Oklahoma, 4000 feet of drilling in shales and limestones showed a carbon loss of only 3c per foot of drilling, and many thousand feet of drilling in similar formations in the Texas, Colorado, New Mexico, Illinois and Mexico show a loss of less than 10c a foot. Such results would not be secured in all cases, but they are sufficient to show that the carbon loss in sedimentary formations is not a serious cost factor.

(3) *Expert labor required to set the bits.* The work in northern Oklahoma, already referred to, shows that a single bit would run from 400 to 800 feet before the metal had been worn sufficiently to require resetting. It is evident, therefore, that resetting may be required only once or twice a month; that, should a company desire to limit its investment to a single bit, there would be no serious loss of time involved for resetting; and, that, while expert services are required when the bit must be set, the setter need not be retained for this purpose only but can be employed on other work in connection with the operating of the drills. On many of the one-drill jobs, the setter is not an extra man, but runs the drill on one tower and at the infrequent intervals, when resetting the bit is necessary, takes a few hours off (not more than three for the ordinary size of bit) for this purpose. If enough carbon is carried for two bits, he can set the extra bit on a Sunday, or in a short time when he is off tower. In larger or more difficult operations, where the services of a foreman would be required, regardless of what method of drilling is used, this man can set the bits when necessary without in any way interfering with his duties as foreman.

Summarizing the points made above: (1) Diamond drills are now made to drill holes of large diameter, and these drills can be used in combination with cable-tools outfits, or for the rotation of fish-tail bits of the rotary type. (2) "Washing" or wearing of cores is prevented by the use of the double tube core-barrel. (3) The investment in carbon is not large compared with the value of other drilling equipment, and is fre-

quently saved in full by lower transportation and casing costs made possible by diamond drilling. (4) Actual carbon wear in sedimentary formations of the oil districts is very small. (5) Bits will run several hundred feet without resetting. (6) The diamond setter is not an expensive and partially employed extra, but will also run the drill on one tower on a one-drill job, or will act as foreman where several drills are at work, or where a particularly difficult drilling operation warrants the sevices of a "tool pusher" for the given job.

Minneapolis, Minnesota. P. W. DONOVAN.
Feb. 16, 1922.

GEOLOGICAL NOTES

PRELIMINARY REPORT ON UNDERGROUND CONDITIONS IN THE HAYNESVILLE OIL FIELD, LOUISIANA

On June 30, 1921, the Bureau of Mines made a preliminary typewritten report on Haynesville, Louisiana, accompanied by a small map of the field and four cross sections, which was sent direct to the companies actually operating in that field. As only about a dozen copies of these reports were distributed, it is available to but few and therefore a few of the points mentioned are repeated here.

The first well was the Roxana Petroleum Corporation's Taylor No. 1 drilled to a depth of 2,902 feet, or a distance of 52 feet below the top of the pay sand. This well was drilled with a rotary and the sand was not tested by lowering the fluid level. A column of mud fluid with a specific gravity of 1.2, 2,850 feet in height, exerts a pressure at the base of 1,484 pounds to the square inch, whereas, the rock pressure at this depth does not probably exceed 500 pounds to the square inch. Smitherman, et al, who originally blocked the acreage on advice of J. Y. Snyder and gave part of it to the Roxana for certain tests, cleaned out the old hole during November, 1920, and found some oil which caused them to drill a new well on the location on the south. The discovery of the oil sand in the second well was accidental and was due to lowering the fluid in the well and creating a suction by pulling out a plug bit.

The cross-sections show the Nacatoch sand at a depth of about 2,100 feet and the producing Blossom sand at a depth of about 2,800 feet. The former contains water. Plotted maps of the well log of the discovery well at ElDorado and a well at Homer can be obtained free from the National Petroleum News, Houston, Texas. The structure, as shown in the sections, is a nose with a north and east dip.

A table is given which shows the safe depth at which casing can be used and the report recommends that 6 inch line pipe weighing 19.36 pounds per foot is not sufficiently heavy for the wells:

Size Inches	Weight Per ft. Lbs.	Collapsing Pressure Pounds Per Sq. In.	Equi. Water Press. Cu. Ft.	Safe depth to use with factor of safety of 2.; Feet.
4½	12.74	2900	6680	2340
6	19.36	2277	5246	2623
	23.50	3114	7175	3587
8	25.41	1397	3220	1610
	29.21	1849	4262	2132
10	32.51	863	1988	994

By W. W. Scott

INVESTIGATIONS ON PERMEABILITY AND ABSORPTION OF "SANDS" FOR OIL, WATER, AND GAS, WITH REFERENCE TO THEIR NORMAL AND POSSIBLE YIELD.*

Experiments have been started by the U. S. Geological Survey on the rate of flow of oil, water, and gas under physical conditions as nearly as possible like those that exist in nature. The effect of cementation, size and shape of pores and grains, percentage distribution of sizes of grains, total pore space, unconsolidated fine material in pores of samples, and such other physical properties as pressure, temperature and viscosity of oil, which cause variations in the flow of oil through "sands," are to be studied. Experiments are to be made on the effect of the above-mentioned factors on absorption and retention of oil and water by their "sands."

Experiments will be made on chunk samples of "sands" of different physical properties from productive beds at various horizons to ascertain the percentage of recovery of oil by such methods as vacuum, compressed air, water flooding, and steam. In conjunction with these experiments, microscopic examinations of small fragments of the oil "sands," as well as of thin sections of these "sands," are being made to determine shapes and sizes of grains and pores, the mode of occurrence, location, and nature of the cementing material in the pores, and the manner in which these characteristics vary at different positions on anticlines and other structural features.

A comparative study of "sands" of the different fields of the United States and an intensive study of the application of experimental results to "sands" of specific areas or pools will be made. It is hoped that these studies will not only aid in the development of a field after it is discovered, but lead to a much better understanding of the forces that operate in the accumulation and migration of oil.

The work has been somewhat retarded by difficulty in obtaining suitable samples for the experiments, especially from wells distributed over a single pool. Samples of oil "sands" taken at random are of value, but to obtain the best results series of chunk samples must be taken from a well, showing variations in the "sands" from the top of the cap rock to the bottom of the "sand." The best material is diamond-drilled cores, and recent activities indicating that more and more drilling with core-saving machines is in progress are looked upon as presaging a much more complete knowledge of oil "sand" conditions than has heretofore been obtained.

The first progress report on this work, The Determination of Pore Space of Oil and Gas Sands, by the writer, was published in the Bulletin of the American Institute of Mining and Metallurgical Engineers for April, 1920. This report gives the progress of the work up to the time of publication.

A. F. MELCHER.

Washington, D. C. Feb. 15, 1922.

*Published by permission of The Director, U. S. Geological Survey.

OIL AND GAS PROSPECTS IN GARFIELD COUNTY, MONTANA

Detailed examinations of the geology of parts of Garfield County, in east-central Montana, south of the Missouri and east of the Musselshell, have been made by C. F. Bowen, Frank Reeves, W. T. Thom, jr., and C. E. Dobbin, of the United States Geological Survey, and reconnaissance examinations of the remainder of the county have been made by A. J. Collier, W. T. Thom, jr., and C. E. Dobbin.

GEOLOGIC STRUCTURE

A broad, shallow structural trough, called by Reeves the Blood Creek syncline, crosses Garfield County from west to east, passing near Ross and a short distance south of Jordan and Van Norman. In the region north of this trough the beds rise with a gentle and even slope, but in the region south of it they rise more rapidly and irregularly toward the zone of uplift that includes the Cat Creek, Alice dome, and Porcupine areas. The principal structural feature of the county is therefore a wide shallow tilted slightly toward the east, whose southwest rim is turned up rather steeply and somewhat crumpled.

SEDIMENTARY ROCKS

The rocks of possible interest to the oil producer that are exposed at the surface in Garfield County or that are believed to underlie it comprise about 8,000 feet of sedimentary strata, which belong to the formations described below. The formations are described below in order from the latest to the earliest.

The Fort Union formation, of early Eocene age, consists of beds of yellowish clay and sandstone of fresh-water origin and numerous persistent beds of lignite. The thickest remnants of the formation are found in the southeastern part of the county, where they probably attain a maximum thickness of about 450 feet.

The contacts between the upper Fort Union and the Lebo shale member, and between the Lebo and the underlying Lance, as mapped by Rogers[1], have not been traced over Garfield County. However, between the yellow strata of the high divides and the somber-hued badlands formed by the lower part of the Lance there is a zone that probably represents the Lebo shale, in which beds of thick rusty-red sandstone alternate with beds of dark shale containing lenses of crystals of glassy feldspar and pebbles of pumice. The base of this zone is placed tentatively at the bottom of the Big Dirty coal bed (Barker coal), which is mined near Sand Springs and which is conspicuously developed along the west side of the Musselshell-Dry divide and around Chalk Butte, near the head of Snow Creek. A similar dirty coal bed, probably the same bed, is exposed in the bluffs of Dry Creek just east of Van Norman. The thickness of the Lebo (?) member is variable but probably averages about 125 feet.

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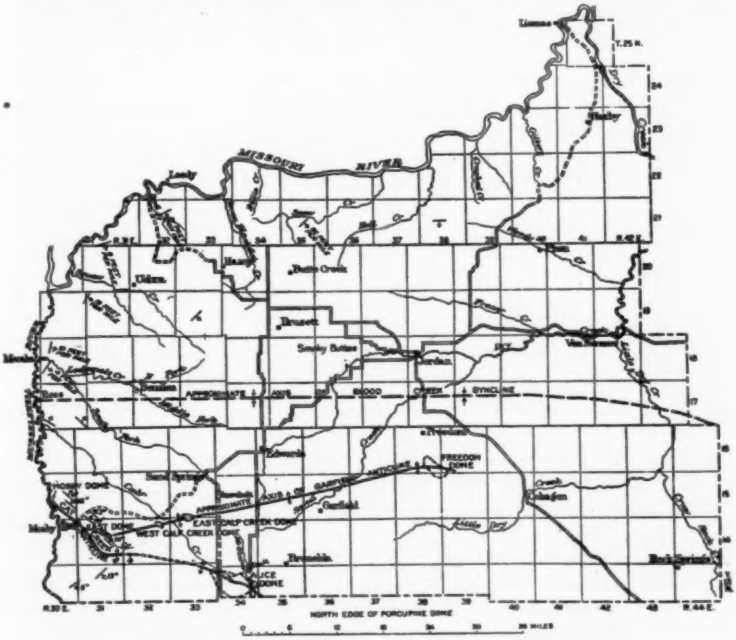
[1]Rogers, G. S., The Little Sheep Mountain Coal Field, U. S. Geol. Survey, Bull. 531.

The Lance formation covers the surface of more than half of Garfield County. Its top is tentatively placed at the bottom of the Barker coal, so that it seems to be divisible into an upper and a lower member. The upper member, which consists of beds of soft yellow sandstone and sandy shale containing thin but persistent beds of lignite, shows a decided contrast in color to the darker beds above and below and has a thickness of about 150 feet. The lower member is about 550 feet thick and is com-



STRUCTURAL SKETCH MAP OF GARFIELD COUNTY, MONT.

Plate I.

posed principally of somber sandy shale but includes some massive irregular sandstone, especially near its top and its base. It is the surface formation of the Missouri "breaks" and of the lowlands of the Dry Creek valley, and it contains many bones of dinosaurs.

Below the Lance formation there is a conspicuous white sandstone that closely resembles the Fox Hills sandstone of the region south of Glendive, which is of Upper Cretaceous age and is the top formation of the Montana group. In Garfield County, as in the region near Glendive, the top of this white sandstone was considerably channeled before the sand that formed the brown sandstone which at many places overlies it, was laid

down upon it. Below this white sandstone is a transitional zone of thin marine sandstone and sandy shale, which merge gradually into the underlying normal Bearpaw shale. The thickness of these sandy beds tentatively referred to the Fox Hills ranges from 30 to 115 feet.

Beds of dark marine shale of the Bearpaw formation, of Upper Cretaceous age, which underlies the Fox Hills (?) sandstone, are exposed in a narrow belt along the northern and western borders of the county and along its southern line as far east as R. 39 E. They are exposed also along the axis of the Garfield anticline in the valleys of Calf and Sand creeks and on the crest of the Freedom dome. The thickness of the Bearpaw probably averages about 950 feet in Garfield County, although it seems to decrease somewhat toward the Porcupine dome and the Cat Creek uplift.

Sandstone and clay belonging to the Judith River formation are exposed along the northern margin of the Porcupine dome, on the southern line of the county between Rs. 35 and 39 E. inclusive, and form the crest of the Alice dome, in T. 13 N., R. 34 E. They also form the major rim or hogback that encircles the eastern end of the Cat Creek anticline. The formation is of fresh-water origin in the western part of the county, where it has a thickness of about 200 feet, but it grades into marine sandstone toward the east and grows thinner in that direction.

Beds of dark marine shale that include yellow and brown concretionary beds and that belong to the Claggett formation are exposed on the flanks of the Cat Creek anticline, where the formation has a thicknes of 430 to 600 feet.

The basal formation of the Montana group, of the Upper Cretaceous series, is the Eagle formation, which outcrops in a zone of buff sandy shale about 75 feet thick near Mosby. Beneath the surface in the central and eastern parts of Garfield County this formation is probably represented by shale.

The upper members of the Colorado shale are exposed on the crest of the Cat Creek anticline and are the oldest rocks that come to the surface in Garfield County. At Cat Creek the formation is about 1,740 feet thick and consist principally of dark shale, but includes some concretionary beds. The thin sandy limestone that is known to drillers as the Mosby sand, and the Mowry shale member, lie 1,070 and 750 feet respectively above the Cat Creek sand, which has been selected by Reeves as the local base of the Colorado (in which it is included), and which is therefore in the general position of the Dakota sandstone.

At Cat Creek the Cat Creek sand is underlain by about 500 feet of red and variegated shale and coarse gray and yellow sandstone belonging to the Kootenai formation, of Lower Cretaceous age. At least some rocks representative of this formation probably underlie all of Garfield County.

According to Reeves, the Kootenai of the Cat Creek area is underlain by about 600 feet of probably Lower Cretaceous and Jurassic beds belonging to the Morrison and Ellis formations. These beds probably consist

of variegated shale in the upper half and of sandstone, shale, and limestone in the lower half and include some red shale at the base.

Reeves estimates that at Cat Creek this formation consists of 1,300 feet of gray, green, and black shale, black and gray limestone, and hard fine-grained sandstone. Fossils recently collected from the very top of the formation in the Big Snowy Mountains are believed to be of upper Mississippian age, though they may be lower Pennsylvanian.

The Madison limestone is of lower Mississippian age, and Reeves tentatively assigns to it a thickness of 2,100 feet at Cat Creek.

IGNEOUS ROCKS

The only rocks of igneous origin known to be exposed at the surface in Garfield County are those of Smoky Butte, a prominent landmark 10 miles west of Jordan. The igneous material occurs here as a large dike, which cuts strata as young as the basal part of the Fort Union formation.

HISTORY OF DEVELOPMENT

No wells have yet been drilled for oil or gas in Garfield County except on the Cat Creek fold. Prior to October, 1921, only three wells had been drilled, all in the area south of the axis of the Cat Creek fold. These obtained shows of oil in the Cat Creek or the Kootenai sands but made no commercial production. In October, 1921, Antelope No. 1 well, drilled by the Frantz Corporation in the northwest corner of sec. 26, T. 15 N., R. 30 E., was completed at a depth of 1,094 feet and is reported to have produced oil at the rate of about 100 barrels a day for some time after its completion.

The test well of the Montana Syndicate, in the southwest corner of sec. 15, T. 15 N., R. 30 E., was still being drilled at latest reports. The Mosby Oil Co. found water in the Cat Creek sand at 780 feet in the NW. ¼ NE¼ sec. 21, T. 15 N., R. 30 E., and the Mosby Dome Syndicate is reported to have obtained a good show of gas at 1,035 feet in their test well in sec. 34, T. 15 N., R. 30 E. Northern Pacific No. 1 well of the Frantz Corporation, drilled in the NE. ¼ Sw. ¼ sec. 27, T. 15 N., R. 30 E., obtained water in the upper sand and is reported to have been abandoned after having been drilled below 2,600 feet. The position of this well, which is south of the surface axis and structurally below the principal domes, is believed to have been unfavorable to the success of the test in view of the subsurface structural conditions which are thought to exist at Cat Creek.

The test well of the Absaroka Oil Development Co., the NE. ¼ NE. ¼ sec. 1, T. 14 N., R. 30 E., obtained water in both the Cat Creek and the Lupton sands (the latter a sand in the Kootenai formation) and was abandoned.

PROSPECTS OF OBTAINING OIL IN GARFIELD COUNTY

Cat Creek anticline—As has been already stated, a small quantity of oil has already been obtained in Garfield County in the northwest corner

of sec. 26, T. 15 N., R. 30 E. From the map published by Lupton and Lee[2] it is apparent that this oil comes from the faulted belt north of the surface crest of the fold, and it is this general zone which is believed to be the more promising, especially the parts of it that lie north of the domes. It is also believed that the point of intersection of the axis of the Cat Creek fold with that of the Garfield fold, which should lie near or slightly northwest of the center of T. 14 N., R. 31 E., will probably be marked by a slight local dome, which possibly contains some oil. Experience in the Cat Creek field has shown that the crest of the fold in the Cat Creek sand lies several hundred feet north of the place where the crest appears at the surface, and the deeper beds will probably be offset still farther northward, to an extent proportionate to their greater depth. This interpretation is based on the belief that the steep north flank of the Cat Creek fold overlies a fault in the deeper rocks, and the similarity of the form of the Cat Creek fold to other pronounced folds in Montana suggests that, in testing the folds there that show steeper dips on one side than on the other, at least one test well should be located on the side of the steeper dip a short distance from the place where the crest appears at the surface.

The apparent presence of oil in the Madison limestone in the Soap Creek field and the occurrence of oil in the lower part of the Quadrant in the Devils Basin suggest that these horizons should be tested in the Cat Creek field. Apparently the most favorable location for a test well would be on the north side of the Mosby dome, in the valley of the Musselshell, where, according to estimates by Reeves, the top of the Madison should probably be reached about 3,200 feet below the surface. It may, however, be necessary to drill to a depth of 3,500 feet.

Alice dome—The Alice dome lies on the zone of uplift that connects the Cat Creek fold with the Porcupine dome. It is estimated that the crest of the Alice dome lies somewhat north of the center of sec. 10, T. 13 N., R. 34 E., that the Cat Creek sand should probably be reached between 2,550 and 2,850 feet below the lowest rocks exposed on the crest of the dome; and that there is somewhat more than an even chance that a commercial pool of oil will be found beneath it.

Garfield anticline.—The Bearpaw shale has been exposed where Calf Creek crosses the axis of the Garfield anticlne, and this shale area is usually referred to as the Calf Creek dome, but this area may perhaps be divided structurally into the East Calf Creek and West Calf Creek domes, whose approximate location is shown on the accompanying sketch map. The West Calf Creek dome may actually be devoid of closure, although it probably has a closure of a few feet, as compared with about 100 feet on the East Calf Creek dome. The axis of the Garfield anticline east of the East Calf Creek dome probably sags in secs. 34 or 35, T. 15 N., 33 E. East

[2]Lupton, C. T. and Lee, Wallace, Geology of the Cat Creek oil field, Montana: Am. Assoc. Petroleum Geologists Bull. vol. 5, No. 2, p. 256, 1921.

of this sag the beds rise about 175 feet in 5 miles, but it is not known whether the axis then continues approximately level or whether it undulates and produces additional domes. According to an unconfirmed rumor an uplift, usually referred to as the Jordan dome, lies on the axis of the Garfield anticline northeast of Garfield post office. The Freedom dome, which probably marks the east end of the Garfield anticline, is near the southeast corner of T. 16 N., R. 38 E. Observations made indicate that the northeast flank of this dome dips 18° to 20°, and maps courteously provided by the Absaroka Oil Development Co. show that the dome has a considerable closure. The Freedom dome is believed to be somewhat less promising than the Alice dome as a source of oil. The East Calf Creek dome and such other domes as may exist on the Garfield axis between Calf Creek and R. 37 E., are in turn believed to be less promising than the Freedom dome. It is therefore recommended that the Fredom dome be tested before drilling is undertaken elsewhere on the Garfield anticline. On all the domes mentioned it is estimated that the total thickness of the beds that lie between the top of the Bearpaw and the Cat Creek sand is about 3,800 feet, which is an approximate measure of the depth of projected test wells, as only a little of the Bearpaw has been eroded from these uplifts.

Remainder of the county.—West of Sand Springs, between the Garfield anticline and the Blood Creek syncline, there is an area in which the strata have been slightly flexed, producing domes that are so small and low that there is no likelihood of obtaining oil from them in commercial quantities. No structural uplifts favorable to the accumulation of oil are believed to lie north of the Blood Creek syncline, and the remainder of the county is not believed to contain favorable uplifts, other than those already mentioned, although only a hasty reconnaissance has been made of the extreme eastern and southeastern parts of the county.

POSSIBLE OIL SANDS

As has been pointed out, the Cat Creek sand and the sand of the Kootenai formation are the more probable sources of oil in Garfield County. The sand of the Ellis and the Quadrant formations and also the Madison limestone may possibly yield oil on the Cat Creek anticline, but elsewhere in the county they lie too far below the surface to be considered.

It is possible, though not probable, that the Eagle sandstone and Mosby sand may yield oil or gas in the county, and there is a slight possibility that marine sandstones of Judith River age may yield oil or gas in the domes along the Garfield anticline.

ACCESSIBILITY AND OPERATING CONDITIONS

Garfield County will be crossed by a proposed line of the Great Northern Railway, but it is remote from existing railroad lines. The northeastern part of the county is served by the towns of Uashua and Glasgow, on the Great Northern Railway, by means of a ferry at Lismas, and a

daily stage line connects Jordan with the Northern Pacific and the Chicago, Milwaukee & St. Paul railways at Miles City. A stage also runs three times a week between Sand Springs and the Chicago, Milwaukee & St. Paul Railway at Sumatra. The terminus of a branch of this railway at Winnett is about 20 miles west of Mosby and is the shipping point for concerns operating in the Cat Creek district. Except for this district the remainder of the southern and western parts of the county is most readily accessible by the roads which lead from Sumatra, Ingomar, and Miles City to Sand Springs, Edwards, and Jordan, respectively. The much-traveled "Green Trail," from Glendive to Lewistown, runs through Van Norman, Jordan, Edwards, Sand Springs, and Mosby. The accompanying sketch map shows the principal roads of the county and indicates which of them have been graded.

The drainage basin of Dry Creek above Van Norman has a gently rolling topography of moderate relief. The southern and southeastern parts of the county are somewhat rougher and have a maximum elevation of 600 or 700 feet above Dry Creek at Van Norman. The remainder of the marginal part of the county, in the lower valley of Dry Creek and along the Missouri and the Musselshell, is noted for its badland topography, of which the valley of Hell Creek is a well-known example. The maximum relief in this badland belt is about 1,000 feet, and the extreme dissection makes travel circuitous or difficult and renders numerous small areas inaccessible to vehicles.

Dry and Little Dry Creeks and their tributaries drain the greater part of Garfield County. A number of minor creeks, the largest of which are Hell Creek and Snow Creek, drain the northern badland area, and Squaw, Lodgepole, Calf, and Sage Hen creeks are the principal tributaries of the Musselshell that rise in western Garfield County. All these streams may cease to flow during dry periods late in summer, and their courses are then marked by small pools of standing water. The construction of dams, and the storage of water is therefore a warranted precaution before extensive drilling is undertaken, although artesian water will probably be found in the Judith River sandstones and also in the basal sandstones of the Lance in the central part of the county.

The numerous local lignite prospects would probably afford the cheapest fuel for drilling operations in Garfield County, though coal may be obtained from the railroad at Sumatra or Ingomar, or oil might be brought from Cat Creek, in spite of steep hills east of the Musselshell, which make heavy hauling from Mosby both difficult and costly.

W. T. THOM, JR., AND C. E. DOBBIN.

AGE OF THE BARNETT (LOWER BEND) SHALE OF CENTRAL TEXAS

Between the well known Marble Falls limestone which is so important as an oil producer in the north Texas fields, ad the underlying Ellenburger (Ordovician) limestone there is present in most places a soft,

yellowish gray to black, clayey, bituminous shale. This shale was first differentiated from the associated strata by Udden [1] who described its occurrence at the outcrop in eastern San Saba County and included it under the name "Lower Bend shale" with the Bend series. Udden referred the Bend series to the Pennsylvanian. In a recent paper by Plummer and Moore[2] the Lower Bend shale has been given the name Barnett shale from a locality a few miles east of the town of San Saba in the Central Mineral Region where the shale is well exposed. Descriptions of lithologic character, measurements of outcrops, observations of stratigraphic relations and discussion of the contained fossils and their correlation are presented in this paper. Following the conclusions of the present writer reported in a paper read before the Association in 1919[3], the Barnett shale is tentatively referred to the Pennsylvanian, in the contribution by Plummer and Moore though on account of conclusions by Girty[4] that the lower Bend shale is really Mississippian, the division is placed under the heading "Beds of Uncertain Age."

The chief reasons for the correlation of the Barnett shale with the Pennsylvanian which has previously been proposed may be reviewed briefly. (1) The stratigraphic relations of the Barnett hale appear to indicate a close association with the overlying Marble Falls, limestone which is unquestionably lower Pennsylvanian. The Barnett shale rests with profound unconformity on the eroded surface of the Ordovician limestone but no evidence of an erosion break between the Barnett and Marble Falls was observed in the field. It may be concluded that the sequence of muddy clastic sediments represented by the Barnett shale and included limestone in the upper part and the overlying Marble Falls limestone, are the normal expectable sequence of deposits in a sea gradually advancing on the Llanorian old-land. Mississippian deposits, excluding from consideration the Barnett shale, are unknown in this region, either at the outcrop or from well records to the north. It may be regarded as rather unlikely, *a priori,* that the sea in which the Barnett was deposited marks a separate advance of the sea from that which left its record in the Marble Falls limestone. The stratigraphic relations of the shale and the physical history of the region appear to unite more or less closely the Barnett shale and the Marble Falls limestone. (2) Paleontologic evidence suggests a relationship between the Barnett shale and some of the formations, such as the Caney and Moorefield shales, which have been classified as upper Mississippian, but it has not seemed certain that the fossils

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[1]Udden, J. A., et al., Review of the geology of Texas, Bur Econ. Geol. and Tech., Texas, Bull. 44, p. 42, 1916.

[2]Plummer, F. B., and Moore, R. C., Stratigraphy of the Pennsylvanian formations of north-central Texas, Univ. of Texas, Bull. 2132, p. 23, 1921.

[3]Moore, R. C., The Bend series of central Texas, Bull. Am. Assn. Petr. Geol., vol 3, p. 218-19, 1919.

[4]Girty, G. H., The Bend formation and its correlation, Bull. Am. Assn. Petr. Geol., vol. 3, pp. 71-81, 1919.

from the Barnett shale were really identical with those from Mississippian beds elsewhere. Consideration of the faunal evidence is presented in some detail in the paper by Plummer and Moore[5] which has been mentioned. It may be noted here that the somewhat doubtful record of *Fusulina*[6] in the Barnett shale and the nature of other fossils are in-
Saba. Other specimens have not been found.
dicative of or are not inharmonious at least with the correlation of the Barnett with the Pennsylvanian, and that some fossils such as the coral *Paleacis*, in the Marble Falls, which occurs high in this formation, are elsewhere indicative of the Mississippian. There are a number of elements in the fauna of the Bend as a whole that are evidently derivative from the Mississippian and are more or less strongly suggestive of it. In short, it has ben believed that the faunal evidence is in keeping with the conclusion that the Barnett shale marks the initial deposit of an advancing sea of early Pennsylvanian time in this region.

Studies of the cuttings from wells which were drilled through the Bend at three points north of the outcrop in San Saba and adjoining counties in central Texas have convinced Goldman[7] that there is a break, marked by a zone of glauconite and phosphatic pebbles, between the Marble Falls and the black Barnett shale. It may be recorded here that following the 1921 meeting of the American Association of Petroleum Geologists at which the conclusions of Goldman were presented and discussed, arrangements were made by the U. S. Geological Survey for examination of the outcrops of the Barnett shale in San Saba County. A party consisting of Messrs. Goldman, Sellards, M. G. Cheney and the writer visited exposures of the Barnett-Marble Falls contact southeast and south of the town of San Saba and made careful observations of the beds in question with special reference to the occurrence of glauconite and phosphate pebbles and the distribution of fossils. Among the localities visited was that described by Moore[8] on upper Cherokee Creek southwest of the town of Bend where the occurrence of abundant Barnett fossils had been reported in limestone which there was thought to represent the base at the Marble Falls formation.

It was found in all of the localities examined that there is more or less glauconite and phosphatic material at the top of the shale or at a horizon which may be regarded as marking the contact between the Barnett and Marble Falls and that the fossils peculiarly characteristic of the Barnett division do not range above this thin glauconitic and phosphatic zone. In the exposure on Cherokee creek the top of the Barnett division, thus defined, is a hard, drab extremely fossiliferous limestone not different

[5] Plummer, F B., and Moore, R. C., loc. cit., pp. 26-32.

[6] A single specimen which is apparently referable without question to *Fusulina* was contained in a collection of fossils made by Mr. Plummer from marly beds in the Barnett shale near Barnett Springs, east of San

[7] Goldman, Marcus I., U. S. Geol. Survey, Prof. Paper 125, 1920.

[8] Moore, R. C., loc. cit., p. 224.

lithologically from many parts of the Marble Falls, but this bed of fossiliferous limestone is separated from the succeeding massive limestones by a thin parting, 1 to 3 inches thick, composed of clayey, glauconitic and phosphatic material. The fossils from the limestone below the thin break were not found above this layer and brachiopods found in the basal part of the Marble Falls limestone at this point were not found in the very fossiliferous limestone below the glauconite zone. The same essential conditions were found at the excellent exposure of the lower Bend rocks about two miles southeast of San Saba on the San Saba-Chapel road.

This evidence indicates that there is in fact a line of demarcation between the Barnett and the Marble Falls which is indicated by a zone of glauconite and phosphatic pebbles, and this line separates two distinct faunas. There is no question but that the fauna of the Barnett as thus defined is more closely related in its aspect to the Mississippian than the Pennsylvanian and that it is not continuous with the Marble Falls. As indicated in a more recently published summary of the north central Texas Pennsylvania[9] the Barnett may accordingly be referred tentatively to the Mississippian in accordance with Girty's earlier correlation. However it may be recalled that in formations such as parts of the Morrow and the Wapanucka, in Arkansas and Oklahoma there are fossils which are even more suggestive of Mississippian age than any found in the Barnett, yet these formations are commonly regarded as early Pennsylvanian. While it is significant that a definite line of division between successive faunas in the lower part of the Bend coincides with the glauconitic and phosphatic zone described by Goldman it may be recalled that there are a number of such glauconitic and phosphatic zones in the Bend.

The writing of this statement concerning the Barnett shale has been considerably delayed but it is believed that those who are engaged in the study of north Texas geology should be advised of the observations made at the outcrops of the Bend. In conclusion, it may be noted that, notwithstanding the demarcation of the Barnett from the succeeding formations which is now indicated, and the tentative reference of the shale to the upper Mississippian rather than the lower Pennsylvanian, the writer believes that there are a number of reasons, as stated in the early part of this discussion, for continuing to regard as unsettled the final correlation of the Barnett.

RAYMOND C. MOORE.

THE OIL AND GAS FIELDS OF ILLINOIS

The locations of the oil and gas fields, pipe lines, refineries, and anticlinal axes in Illinois are shown on a map printed in three colors, on a scale of 8 miles to the inch, just published by the United States Geological

[9] Moore, Raymond C. and Plummer, F. B., Jour. Geol., vol. XXX, p. 28, 1922.

Survey. These features are superimposed on a base map that shows counties, cities, railroads, and drainage, but the features of the oil and gas fields are made prominent by printing the base in gray, which though legible, does not interfere with the other data.

In the preparation of the map the best inormation available to the Geological Survey was utilized, and the map was subsequently improved by incorporating in it revisions and additions made by the Illinois Geological Survey as well as by geologists and officials of oil, gas, and pipe-line companies operating in the State.

This map, which should be value to producers, refiners, and others who are interested in the oil and gas fields of Illinois, is sold for 50 cents a copy by the Director of the United States Geological Survey, Washington, D. C.

SOUTHERN MEXICO

Mr. Fred B. Ely reports that work in the states of Colima and Oaxaca, Mexico, is very interesting, but not very profitable from an oil production standpoint. The general type of fault block structure which is so characteristic of the Sierra Madre Mountains holds good for all of the coastal country as far south as Michoacan. There is no real coastal plain or folded sedimentary strata such as are ordinarily associated with oil deposits. Some individuals in this region are, however, sufficently eager in the search for oil that they are preparing to drill on a volcanic plateau. "Chapapote," or at least material called that, is shown in beds of volcanic ash. South of Lake Chapala, Jalisco, is an interesting deposit of asphaltic material in Quaternary clays and shales in a volcanic basin. Similar deposits of asphalt have been reported in the southern part of Chiapas, though none are known to be of commercial importance.

REVIEWS AND NEW PUBLICATIONS

FULLER'S EARTH DEPOSIT AT OLMSTEAD, ILL.

By Cullen W. Parmelee

Chemical and Metallurgical Engineering, Jan. 25, 1922, p. 177

About 1912 J. H. Gardner of the Kentucky Geological Survey noted some peculiar deposits in the Ohio River bluffs near Olmstead, Illinois, and sent samples of the material to C. C. Ruprecht, who had had considerable experience with fuller's earth. The latter tested these and other samples, optioned some land, and with associates erected a mill which has operated for more than a year. Recently the Sinclair Refining Company of Chicago has taken over this mill with 55 acres of adjoining land, and last summer the Standard Oil Company of Indiana purchased 155 acres near Olmstead, Illinois. Fuller's earth, a variety of clay formerly imported from England, is now produced in Florida, Georgia, Texas, Alabama, Nevada, Arkansas, California, Massachusetts, and Illinois. In 1920 a domestic production of 128,487 tons was valued at $2,506,189, and imports reached $221,893. Its principal use is to bleach mineral, animal, and vegetable oils.

The deposit at Caledonia, Illinois, near Olmstead, is in the Midway formation of the Tertiary, and occurs in a bluff over 100 feet high which extends along the river bank for about two miles. The section consists of about 10 feet of loose overburden underlain by 34 feet of high-grade fuller's earth. Below this is an additional 30 feet of the material rated as 80 per cent efficient. The material is shot, loaded on to wheelbarrows, and taken to the mill where it is crushed, heated in a rotary oil-bearing dryer to about 900°F. and the moisture is thus reduced to 3 to 5 per cent. Further crushing and screening produces three grades 16-20 and 30-60 mesh, for bleaching and filtration of mineral oil, and 60-300 mesh for filtering lard, vegetable oils, soap stock, etc. The sacked material is hygroscopic and increases its moisture content to 12 per cent during shipment. A production of 350 tons per month is reported with reserves estimated at four million tons.

Since this article was prepared but prior to going to press, the mill at Olmstead was destroyed by fire, and plans for rebuilding same have not been anonunced, but because of the importance of the deposit and its central location, an early resumption of activity is to be expected.

James H. Hance.

THE MONROE GAS FIELD, LOUISIANA

By H. W. Bell and R. A. Cattell

Bulletin 9 of the Department of Conservation of the State of Louisiana has been compiled in co-operation with the United States Bureau of Mines, by H. W. Bell and R. A. Cattell, Petroleum Engineers and is distributed by the Department of Conservation, New Orleans, for 50c a copy.

This publication is the best yet submitted by the Department of Conservation and it is hoped that more work along this line will be authorized by the state. This matter is especially interesting at this time, due to the fact that Governor Parker is contemplating establishing a Geological Survey of Louisiana to carry on systematic work relative to the oil and gas industry of that state. Louisiana is one of the few large oil and gas producing states which has no official survey of any description, and as a result great economic loss has ensued by reason of the fact that oil and gas wells have been drilled haphazardly without proper supervision. Due to the soft formations and unconsolidated sands found in the oil producing areas of Louisiana, it is extremely important that some sort of cooperative measure, worked out preferably along the lines of the California State Mining Bureau, will be authorized by the state legislature.

Bulletin 9 outlines the fact that the Monroe gas field is probably one of the greatest potential gas fields yet discovered and has a proven productive area of over two hundred square miles. It is pointed out that the field should supply an amount of gas equal to a production of 150,000,000 cubic feet per day for 43 years. This statement may or may not be exaggerated, as the ultimate production of the gas will depend entirely upon proper operating methods. The chapter devoted to Geologic Features is very incomplete, but as the Bulletin is primarily one of a technical nature, this fact was very likely not stressed purposely.

The authors call attention to the Red River-Alabama Landing fault, as mapped by Veatch, in connection with the structural conditions of the field, but this phase has evidently not been given much attention, as detailed work in the field will reveal the fact that this much discussed fault, in this particular area, trends in a northeast-southwest direction, from in the vicinity of Alabama Landing, on the Ouchita River, to sec. 33, T. 23 N., R. 7 E., Morehouse Parish; and is a fault of very small magnitude and quite recent age, perhaps dating back not longer than the time of the New Madrid earthquake. Vertical displacement in the soft bed of Ouchita River and the physiographic features of the area contiguous to Bayou Bartholomew, as well as the well drilled by the Bell Oil & Gas Company, in sec. 13, T. 22 N., R. 6 E. all tend to prove this statement.

The fault lying along the southeastern flank of the field called the Monroe Fault by the authors, was mapped in February, 1920, but they evidently overlooked this fact and did not know of it until after the Florsheim and Breece wells were drilled in. This is the major fault of the area and extends from in the vicinity of Sicard, northeast to sec. 33, T. 23 N., R. 7 E. In discussing the subsurface geology, no mention has been made of the deep tests in the Monroe Gas Field nor have the red shales, which have been encountered by these wells, been mentioned. They are probably of Lower Cretaceous age.

Some very good data is given in that part of the Bulletin devoted to the gas reservoir and probable life of the field and the quality of the gas is discussed. Mention has been made of the gasoline content, which shows

a very marked decrease westward from the Monroe fault, and tends to prove the statement that the gas has migrated, and is migrating, vertically up this fault and from a deeper reservoir at least in the Lower Cretaceous, and accumulating in the structural "high" west of said fault.

A very authentic history of development is covered and the condition of the field at present is outlined. This section of the Bulletin contains some very important data, from an economic standpoint, as it shows conclusively the enormous waste which has occurred and which is at present going on in the Monroe gas field, and which can be remedied only by proper supervision and applied engineering methods.

The authors have given some very good rules to be followed in the drilling in of wells and the exclusion of water in this district. Figures on the production and consumption of gas in the Monroe field are given and a great many statistics relative to the gas consumption and rate charged for natural and artifical gas in the large cities within pipe line reach of this field are tabulated.

That part of the Bulletin devoted to the possibilities of expansion in the domestic and industrial utilization of this natural resource is all very feasible and too great stress can not be layed upon this by the people of Louisiana.

The carbon black industry is covered in a general way, but greater detail should be given to the listing of carbon black plants, their capacities, and the gasoline absorption plants connected with them. The losses in the manufacture of carbon black are stressed and this is one of the main things in which the state of Louisiana should be interested if they are to conserve their natural resources.

The authors have concluded their Bulletin by making a number of recommendations, all of which should receive the approval of every one interested in the economic production of oil and gas in that section of the country, and it is to to hoped that the state legislature will provide for proper relief along these lines. Taken as a whole Bulletin 9 is a very valuable contribution by the State of Louisiana, even though many phases of the geology of the area are omitted.

Tulsa, Oklahoma J. Wallace Bostick.
Feb. 14, 1922.

THE ECONOMIC ASPECTS OF GEOLOGY

By C. K. Leith

Henry Holt and Company, New York, 1921
457 pages, 13 figures and diagrams

This book is a comprehensive digest of economic geology by one of its most able exponents who brings to his readers not only the critical comments of one of our foremost teachers and practitioners but of one who served as mineral adviser to the U. S. Shipping Board and in other governmental capacities during the Great War, and who thus had opportun-

ity to study in intimate detail the present international aspects of the mineral industry. It is not a text book in the ordinary sense of the term, but it should prove to be a real addition to the desk or library of anyone who is interested in world problems today.

A list of the chapter topics may serve to indicate the extent of the field surveyed. Chapter I, The economic applications of the several branches of geology; Chapter II, The common elements, minerals and rocks of the earth and their origins; Chapter III, Salient features of the geology and classification of mineral deposits; Chapter IV, Some general considerations of mineral resources; Chapter V, Water as a mineral resource; Chapter VI, The common rocks and soils as mineral resources; Chapter VII, The fertilizer group of minerals; Chapter VIII, The energy resources, coal, oil, gas, and asphalt; Chapter IX, Minerals used in the production of iron and steel (the ferro-alloy group); Chapter X, Copper, lead and zinc minerals; Chapter XI, Gold silver and platinum minerals; Chapter XII, Miscellaneous metallic minerals (ores of aluminum, antimony, arsenic, bismuth, cadmium, cobalt, mercury, tin, uranium and vanadium), Chapter XIII, Miscellaneous non-metallic minerals (abrasives, asbestos, barite, borax, bromine, fuller's earth, graphite, gypsum, mica, monazite, precious stones, salt, talc and soapstone); Chapter XIV, Exploraton and development; Chapter XV, Valuation and taxation of mineral resources; Chapter XVI, Laws relating to mineral resources, Chapter XVII, Conservation of mineral resources; Chapter XVIII, International aspects of mineral resources; Chapter XIX, Geology and war; Chapter XX, Geology and engineering construction; Chapter XXI, Training, opportunities and ethics of the economic geologist.

In the discussion of these various topics the author exhibits a refreshing breadth of view combined with terse treatment. Technical descriptions are minimized and the book although of moderate length, has an unusually broad scope. To the student of geology, and of economic geology in particular, this presentation and brief analysis of the broader aspects and international phases of our mineral supplies will prove a most interesting and profitable study. For the business man of the world who would appreciate some of our larger problems which press for solution the book contains a wealth of information and suggestions. Students of human geography will find that the book sheds much light on many of their more important studies. Throughout the book there are numerous references to some of the larger unsolved problems in this field, accompanied with pertinent suggestions as to promising lines of research and attack.

Chapters XIV to XVIII contain much informational and suggestive comment on important and intimately related phases of the subject. The author's perspective and appreciation of the field are well shown in his brief statements of some of the opportunities and responsibilities which confront the economic geologist of today and tomorrow.

Chapter XIX on geology and war brings out some of the many ways in

which this earth science is of critical importance in time of war. Although we hope that armed conflicts may be remote future contingencies, the experiences in the recent war should bring home the value of geology as a weapon of high effectiveness.

Chapter XX on geology and engineering construction summarizes a few of the many applications in this field where the industrial world is availing itself more and more of the applications of earth studies.

Chapter XXI on the training, opportunities and ethics of the economic geologist is a fitting chapter with which to close such a volume. Broad training is necessary for breadth of view, and many of the problems now awaiting solution challenge the most careful consideration of the best trained minds. The field is the earth, and the opportunites are limited only by the individual.

A few quotations may serve to illustrate the character of the treatment accorded the subjects, and the admirable way in which the author presents his views.

> "There is no phase of geology which at some time or place does not have its economic application."

> "The remarkable concentration of the world's mining and smelting around the North Atlantic Basin * * * does not mean that nature has concentrated the mineral deposits here to this extent. It is an expression rather of the localized application of energy to mineral resources by the people of this part of the world. The application of the same amount of energy in other parts of the world would essentially change the distribution of current mineral production. The controlling factor is not the amount of minerals present in the ground; this is known to be large in other parts of the world and more will be found when necessary. Controlling factors must be looked for in historical, ethnological, and environmental conditions."

> "Every country in the globe is deficient in supplies of some minerals. The United States is better off than any other country, but still lacks many mineral commodities. No single continent has sufficient reserves of all mineral commodities."

> "Looking forward to the future, the problem of mineral reserves in general is not one of the possible ultimate amount which the earth may contain—presumably in no case is this deficient—but of the success with which the resource may be found and developed to keep up with the rapid acceleration of demand."

> "At many times in the history of the mineral industry the end has apparently been in sight for certain products; but with the increased demand for these products has come increased activity in exploration, with the result that as yet no definite end has been approached for any one of them. The more immediate problems of the petroleum industry seem to the writer to be of rather different nature: first, whether the discovery and winning of the oil can be made to keep pace with the enormous acceleration of demand; and second, the adjustment of political and financial control of oil resources, the possession of which is becoming so increasingly vital to national prosperity."

> "Exploration is passing from the highly hazardous stage of individual effort into a systematic business with calculable returns."

> "Conservation of mineral resources may be defined as an effort to

strike a proper balance between the present and the future in the use of mineral raw materials."

"Most of the mineral resources have been concentrated by nature in a comparatively few places in the world; and when the two elements of conservation are considered—the materials themselves and the human energy expended in obtaining and using them—it is clear that any measure which interferes with the natural distribution of the favored ores is anti-conservational from the world standpoint."

"The main problem now is not one of total supplies, but of their effective and equitable distribution."

"In short, man is the multiplier and the mineral substance is the multiplicand in the product known as value."

Some of our students in petroleum engineering would probably modify Dr. Leith's statement that "About 50% of the oil in the porous strata of oil pools is ordinarily not recovered because it clings to the rock." As a result of detailed studies covering all of our American oil fields and with an unusually large amount of data available some of our investigators in the U. S. Bureau of Mines suggest that the total oil left in the rocks as unrecoverable under present methods of extraction is about 80% of the original content.

In the chapter on Valuation of Mineral Resources the author states that "In actual practice interest rates used in making valuations vary from 6 to 15 or 20%." J. R. Finlay in his recent book on Cost of Mining extends the upper limit to 50% or even more, and although most valuation work may come within the figures given by Dr. Leith, enough problems with greater hazards do come up to justify keeping the larger figures in mind.

A few more diagrams and illustrations might add to the value of the book without perceptible increase in its bulk. The material is so thoroughly boiled down and condensed that many readers might welcome a little additional assistance in visualizing the pen pictures which the author sketches all through the text.

Economic Aspects of Geology marks an important stage in the application of geology to civilization, and with Spurr's recent book entitled Political and Commercial Geology are two volumes which the reviewer cordially commends to the attention of all who would be thoughtful students of world affairs today.

JAS. H. HANCE.

HAYNESVILLE FIELD, LA.

The Department of Conservation of the State of Louisiana has published Bulletin 11 entitled: "The Haynesville Oil Field, Claiborne Parish, La.," by W. W. Scott of the U. S. Bureau of Mines, and B. K. Stroud, of the Department of Conservation. The Bulletin consists of 26 pages, a large structure contour map of the field and a cross-section through the field. It is distributed free from the Shreveport Office of the Department. Since publication the field has been extended one and one-half miles west and northwest.

HUNTON LIMESTONE PRODUCTION IN OKLAHOMA

Oklahoma Geological Survey Circular No. 10, published in March, entitled: "A Siluro-Devonian oil horizon in Southern Oklahoma," by Geo. D. Morgan, and distributed free, describes the producing horizon of the Nance Syndicate oil well in Sec. 4, T. 4 N. R. 5 E., of the Doan Oil Co.'s test in Sec. 20, T. 5 N., R. 4 E., of the Transcontinental Oil Co.'s test in Sec. 14, Twp. 5 N., R. 4 E., and in the Maud Oil & Gas Co.'s oil well in Sec. 18, T. 7 N., R. 5 E., as Hunton. This is the most important contribution to the study of unconformities in Oklahoma for several years because it shows that the formations of the Arbuckle Mountains extend north of the Mountains for at least 30 miles and at that point are only 3,730 feet deep. The dip of the Hunton limestone in 16 miles is only about 1400 feet. A portion of Oklahoma formerly "condemned" now has excellent possibilities of production. The exact horizon of the unconformity between the Pennsylvanian and Devonian is not accurately determined but is possibly near the Boggy shale.

ARKOSE NORTH OF THE ARBUCKLE MOUNTAINS

Oklahoma Geological Survey Circular No. 11, by Geo. D. Morgan describes, "Arkose of the northern Arbuckle area." Arkose is found very abundantly in the Pontotoc series. It is concluded that "the base of the Pontotoc series is the time equivalent of the period at which the Arbuckle Mountains were worn down to their igneous core."

THE ASSOCIATION ROUND TABLE

A division of the columns of the Bulletin under this heading is incorporated to provide convenient opportunity for official announcements to the members of the Association, for the presentation of matters which are of importance and interest to the Association but which are outside the field of scientific or technical discussion, and for the expression and discussion by members of subjects which relate primarily to the organization, plans and business of the Association. A continuing council table at which may be considered the problems which receive all too little attention at the annual meetings and then only from a relatively small number of the members, is here contemplated.

THE SEVENTH ANNUAL MEETING OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, OKLAHOMA CITY, OKLAHOMA, MARCH 9-11, 1922.

An event of nation wide geological interest and importance is the annual meeting of the American Association of Petroleum Geologists. It would perhaps be proper to say that the event is of world wide interest for of the nearly eight hundred members of the Association many are now in foreign lands, scattered to the ends of the earth. The seventh annual meeting of the Association was held at Oklahoma City, Oklahoma, March 9th to 11th inclusive with headquarters at the Lee Huckins Hotel. For a short time all roads led toward Oklahoma City, and the number of geologists who came together to enjoy the sessions of the meeting and the pleasure of renewed associations surpassed probably that of any previous meeting of the Association. Unfortunately, a number of members who would have been present otherwise were hindered from attending on account of the time selected for the meeting, just before the 15th of March when income tax statements are due. For the benefit of those who were not able to be present at the Oklahoma City meeting a very brief aand informal account of happenings may be of interest.

Registration, which as usual began on the evening before the formal beginning of the session, had accounted for a considerable number of early arrivals before Thursday morning but the greater number began to arrive Thursday morning and shortly crowded the lobby of the hotel to capacity. The business of registering members and visitors, the sale of tickets to Smoker and Banquet, and the distribution of Bulletins kept two tables busy through most of the session. Pressing business of meeting everyone else got the meeting off to a late start the first morning, but finally President G. C. Matson called the convention to order in the Elks Club Hall around the corner from the hotel. The first event was an address of welcome by the Secretary of the Oklahoma City Chamber of Commerce, Mr. Charles H. Hall, whose vigor-

ously earnest and impassioned oratory not only made all of the assembled guests feel glad that they had come, but sorry that it had been necessary to leave the family at home. Dr. Irving Perrine, President of the Oklahoma City Geological Society, cordially seconded the welcome to Oklahoma City. Acceptance and appreciation on behalf of the Association for the courteous hospitality of its hosts having been duly pronounced by the President, there was nothing to do but start the technical sessions. As to these sessions, it may be said simply that the large room of the Elks Hall was packed to near capacity through all the sessions of the three days. The papers and discussion will appear in the columns of this Bulletin. As is customary, the flow of papers rippled placidly along without interruption for certain spaces, then a swirling rapids of discussion was encountered.

Special features on the program, besides the technical sessions, were the Smoker on Thursday night, preceded by a Public Lecture, and the Banquet on Friday night. In addition quite a number of college alumni dinners and luncheons which were held should perhaps be included among the special events. The Public Lecture was given by Professor Charles Schuchert of the Department of Geology of Yale University, his subject being "The Geology of South America." The lecture was held in the commodious and beautifully appointed auditorium of the First Christian Church a short distance north of the center of town. Professor Schuchert's talk was illustrated and was thoroughly enjoyed by a very large audience. The Smoker was held in the rooms of the Oklahoma City Chamber of Commerce. The event was a decided success, for in addition to the customary functions and program of a smoker, tables with "eats" were provided and a variety of clever entertainment was offered, culminating in a song and dance act—do you remember that Doctor Ohern?—which was received hilariously.

Without doubt the most important and most interesting social event in the annals of the Associatioon is the Annual Banquet. Those who attended the Banquet on the Mezzanine floor of the Huckins Hotel Friday evening, will long remember it pleasurably. Under the direction of Mr. Dean Stacey of the Local Committee, very attractively arranged and decorated tables had been provided, but it was found impossible in the space available to care for all who wished to attend and there were tables for the overflow just outside the main room. The Banquet was somewhat less formal than some of the annual dinners of the Association and college spirit was the chief motif in the decorations and preliminary entertainment. The decorations covered not only the tables but also the persons of many of the banqueters, caps and bandeaux of appropriate colors representing the insignia of Chicago, Wisconsin, or as the case might be, being worn by many. The amusement mentioned consisted largely of college yells and impromptu songs. One such song, the lyric of which was composed for the occasion and sung by L. J. Pepperberg and Max W. Ball was a choice bit received with special

relish. Dr. Ohern acted very ably and pleasingly as toastmaster. A beautiful but difficult violin solo, rendered in brilliant manner by Mrs. Frank Buttram began the more formal part of the program. Representing the ladies, Mrs. W. C. Kite charmingly offered a toast, which for the benefit of geologists' wives who were not present and for those who appreciate them, is presented with this account. Prof. J. B. Umpleby, of the University of Oklahoma, talked interestingly and humorously about something we have forgotten but which had to do with the number of a tank car, we believe. Prof. Charles Schuchert briefly and skillfully sketched the development of geology and of geologic research from the distant day when there really was no geology down to the present time. The supreme achievement of a very unusual evening, in the which was acquired a reputation altogether new and unexpected to his friends, but which will remain undimmed through time was the toast of James H. Gardner. There was, we think, no title but the subject had chiefly to do with Cockroaches! Who would have thought that there was any fun in a Cockroach It is unfortunate that along with Robert Burns' "To a Louse" cannot be placed a record of a second classic, Gardner's "To a Cockroach."

A novelty was the taking of a photograph on Saturday noon of the entire convention . It was made with the aid of a specially constructed stand.

Matters of business, the election of officers (notwithstanding the pleasure of making and listening to nomination speeches), etc. will not be mentioned in this account, for that is to be handled more or less formally and officially. In closing mention may be made of the very pleasurable entertainment of the ladies which was provided.

R. C. M.

Toast by Mrs. W. C. Kite

Mr. Toastmaster, Ladies of Faith and Geologists: The lot of a geologist's wife is one of great joys and tribulations. Perhaps this can best be shown by a series of actual telegrams exchanged between a geologist and his wife. The incidents involved might have happened to any of us.

The man of the house comes home in the evening, gets the paper off the front porch, seats himself in a comfortable chair and turns to the last page first—Ira Rinehart's Oil column—of course. Suddenly he gives a shout of excitement and rushes in to his wife, announcing, "We have made our million. The Barry test in Section 29 came in today, making 2000 barrels. We have a lease off-setting that well. I'm leaving tonight to sell that acreage."

After taking her husband to the train, the wife comes home and dreams of dozens of new hats and gowns, a big home, trips to Europe and the like.

The next day she receives the following telegram:

TELEGRAM

Marlin, Texas,
Jan 3, 1922, 1:15 P. M.

Rinehart too free with his ciphers. Well only making two barrels. Be home tomorrow.

The wife decides to get out her last year's suit and send it to the cleaners. The following day another wire comes:

TELEGRAM

Ft. Worth, Texas,
Jan. 4, 10:00 A. M.

Met President of Cheatem Oil Co. Have big deal on. Ought to make $50,000.00. Will wire results.

The wife, in turn, sends the following message:

TELEGRAM

Oklahoma City, Okla.
Jan. 5, 3:00 P. M.

Bobby is lost, strayed or stolen. Shall I advertise?

(Bobby is the dog.)

The answer:

TELEGRAM

Ft. Worth, Texas,
Jan. 5, 6:00 P. M.

Deal blew up. Home tomorrow. Advertise.

The wife cleans house, bakes her husband's favorite cake and devises ways of cheering him up in his saddened frame of mind. Just before time to meet his train the next day comes this disappointment:

TELEGRAM

Sherwin, Texas,
Jan. 6, 11:00 A. M.

Detained several days by consulting job for Big Four Company. Address Hotel Sherwin Texas.

At this juncture the wife begins to get lonesome and misfortune attends her. The man receives the following wire:

TELEGRAM

Oklahoma City, Okla.
Jan. 6, 2:00 P. M.

Send home keys to car. Lost mine. Can't get car in garage.

She receives this reply:

TELEGRAM

Sherwin, Texas,
Jan. 6, 8:00 P. M.

Fine situation! Am sending keys. Heavy rains here. More delay.

A day or two later comes another message:

TELEGRAM

Sherwin, Texas,
Jan. 8, 9:00 A. M.

Lost tripod out of car. Must wait for new one. Home in a few days.

And then comes an accident and the following:

TELEGRAM

Oklahoma City, Okla.

Baby cut his finger. Scared most to death. Doctor says it will be alright. Hurry home.

The answer:

TELEGRAM

Sherwin, Texas,
Jan. 9, 5:00 P. M.

Too bad about the boy. Take good care of him. Be here three or four days longer.

A message comes for the geologist from a client in Wichita. The wife does not know just how to handle the affair so she sends this telegram:

TELEGRAM

Oklahoma City, Okla.
Jan. 10, 7:00 P. M.

Smith of Wichita wires you 'Dry hole on structure you recommended.' Shall I answer?

Reply:

TELEGRAM

Sherwin, Texas,
Jan. 11, 7:00 A. M.

Don't answer.

The wife is worried over the baby and very lonesome by this time. To cap the climax a burglar visits the neighborhood, fortunately overlooking the manless house, nevertheless calling forth this frantic telegram:

TELEGRAM

Oklahoma City, Okla.
Jan. 13, 8:00 A. M.

Come home at once. Afraid to stay alone another minute. Burglars in our block last night. Am going to mother's.

Then comes this reply from Ft. Worth:

TELEGRAM

Ft. Worth, Texas,
Jan. 13, 3:00 P. M.

Stay there. Be home tonight 7:10 Santa Fe. Just heard our other two wells came in today. Both dry holes."

Even if our lots do fall in lonely places and even if he is seldom here to share our joys and sorrows we are mighty proud of our geologist husbands, and always happy over the wanderer's return.

METHODS OF ELECTING OFFICERS

The Constitution Committee of the Association would appreciate suggestions and ideas from the members concerning a more desirable method of electing the officers of the Association. Many innovations have been proposed, such as that of counting first, second, and third choice, that of having ballots mailed by absent members, that of granting proxies to the absent members, that of requiring that 2, 3 or 4 nominees must be voted on for the office of President, that of having nominations published two months before the annual meeting, and several others. The present Constitution Committee has not yet met and before its first meeting it desires to digest and compare the ideas of the members of the Association.

The Committee desires to be able to make a study of the question sufficiently thorough to enable it to give wise recommendations for action by the next annual meeting.

Kindly mail your ideas to the Chairman, Chester W. Washburne, 60 Liberty Street, New York, or confer with any of the following members of the Committee: F. G. Clapp, W. E. Pratt, J. H. Gardner.

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following applicants for membership in the Association. This publication does not constitute an election, but places the names before the membership at large. In case any member has information bearing on the qualifications of these applicants, please sent it promptly to Charles E. Decker, Norman, Oklahoma.

(Names of sponsors are placed beneath the name of each applicant)

FOR FULL MEMBERSHIP:

1. Harry L. Baldwin, Jr., Golden, Colorado.
   Melvin M. Garrett
   K. D. White
   C. W. Washburne
2. William A. Buttram, Oklahoma City, Oklahoma.
   Fred G. Rockwell
   C. W. Shannon
   Irving Perrine

3. James L. Chase, Billings, Montana.
   S. H. Gester
   Wm. L Hubbard
   J. R. Suman
4. Albert F. Crider, Shreveport, La.
   J. P. D. Hull
   G. C. Branner
   R. J. Riggs
5. Robert E. Garrett, Tulsa, Oklahoma.
   L. B. Snider
   Sidney Powers
   W. B. Wilson
6. Sidney E. Mix, Shreveport, La.
   J. P. D. Hull
   S. C. Stathers
   A. E. Hartman
7. George D. Morgan, Ada, Oklahoma.
   C. W. Honess
   F. G. Rockwell
   C. W. Shannon
8. Herbert G. Officer, Tulsa, Oklahoma.
   L. H. White
   George C. Matson
   R. S. McFarland
9. Horace B. Patton, Denver, Colorado.
   Clyde M. Becker
   Eliot Blackwelder
   John L. Rich
10. C. D. Stephenson, Pawhuska, Oklahoma.
    W. L. Walker
    F. L. Aurin
    Sidney Powers

FOR ASSOCIATE MEMBERSHIP:

1. Howell S. Clark, Okmulgee, Oklahoma.
   D. W. Radcliffe
   C. A. Warner
   Harry Nowlan
2. George I. McFerron, Tulsa, Oklahoma.
   J. V. Howell
   Robert J. Davis
   Robert H. Wood
3. Cornelius Schnurr, Tulsa, Oklahoma.
   Richard Hughes
   A. L. Beekly
   Frank C. Greene

4. Rae Preece, Tulsa, Oklahoma.
   Richard Hughes
   A. L. Beekly
   Frank C. Greene
5. Wm. H. Atkinson, Oklahoma City, Oklahoma.
   Willard Miller
   Wm. F. Absher
   C. W. Shannon
6. Glenn O. Briscoe, Ponca City, Oklahoma.
   E. L. Roark
   Everett C. Parker
   Walter M. Burress

A MEETING OF THE ASSOCIATION IN THE FALL

It has been the feeling of a large proportion of the members of the Association that the annual meetings of our organization should be held as conveniently near the center of petroleum geology population—if we may define that sort of population—as possible. Since a large proporton of the petroleum geologists of the country reside in the Mid-Continent and Gulf fields and since the central part of the United States is most easily reached by a majority of the members of the Association, the annual meetings have been held in Oklahoma and Texas. There are many members in the Rocky Mountain region, in the country between the Mississippi and the Appalachians, on the Pacific coast and along the Atlantic seaboard. For these, attendance at a meeting in the Mid Continent is difficult and while a number who have been present at such meetings regularly plan not to miss subsequent gatherings there are many, the majority in each of the districts outside the Mid-Continent who are denied the pleasures of the meetings.

At the meeting of the Assocation in Oklahoma City in March a plan to arrange for a meeting in the Fall outside of the Mid-Continent was proposed and approved. The time and place of this meeting have not been settled. A very cordial and urgent invitation from the strong group of Rocky Mountain petroleum geologists has been received to hold such a meeting in Denver. Meetings of this sort should desirably be arranged in Colorado, Wyoming, California, Illinois, Kentucky, Pennsylvania and elsewhere from time to time. The American Association of Petroleum Geologists will be strengthened by this closer contact with all parts of the country which are concerned with the finding and production of petroleum, and geologists will benefit importantly from the wider association and representation.

Watch for notice concerning the proposed meeting next Fall and plan to be present.

AT HOME AND ABROAD

MR. W. E. WRATHER will lecture at the University of Chicago from April 1st to June 15th and his address will be Rosenwald Hall. His address in Dallas, Texas, is 6044 Bryan Parkway.

MR. HEATH M. ROBINSON is now located in the Great Southern Life Building, Dallas, Texas.

MR. C. W. WASHBURNE will deliver a course of lectures on petroleum geology at Harvard University during the second term. He will be assisted by Mr. K. D. White, who recently returned from Africa.

MR. E. L. JONES, JR., is Chief Geologist for the Comar Oil Company with headquarters at Ponca City, Okla.

MR. ROBERT D. GOODRICH has opened an office at 606 Linz Bldg., Dallas, Texas.

MR. JOHN FERGUSON is geologist for the Borealis Oil Co., of Oklahoma City, Okla.

MR. D. R. SNOW is Chief Geologist for Waite Phillips in the Petroleum Building, Tulsa, Okla.

MR. W. S. W. KEW, of the U. S. Geological Survey is mapping the Palo Verde Hills near San Pedro, Southern California.

MR. O. L. BRACE is employed by Mr. Ralph Arnold at Los Angeles, Calif.

MR. GLEN M. RUBY is working in Utah.

MR. J. E. ELLIOTT, formerly of the Shell Company, and F. C. MERRITT, have opened an office as Consulting Geologists in Los Angeles, Calif. Mr. Elliott is specializing in examination of core samples.

MR. A. M. MACKENZIE, formerly with the Gypsy Oil Co., is spending the winter at Leland Stanford University.

MR. W. R. HAMILTON is President of the Hamilton Oil Corporation which has superceded the Oil Issues Co.

MR. W. A. VER WIEBE has been in New York City on a business trip.

MR. E. B. HOPKINS is in South America.

MR. W. F. ABSHER is Geologist for the Norman Oil Syndicate at Norman, Okla.

PROF. ELIOT BLACKWELDER will spend the summer at Iola, Kansas, and in the fall will take up his work as Professor of Geology at Leland Stanford University.

MR. F. B. ELY is working in Mexico and his address is Apartado 5314, Mexico City.

MR. W. S. ADKINS is Paleontologist for the Mexican Eagle Oil Co., at Tampico, Mexico.

PROF. J. T. SINGLEWALD, JR., has been in Mexico for the interests of the Standard Oil Co.

MR. A. W. DUSTON is President and MR. C. Z. LOGAN, Secretary-Treasurer of the Okmulgee Geological Society.

MR. J. Q. MYERS is living in Tulsa, Oklahoma, and his address is 413 Mayo Bldg.

MR. L. L. HUTCHISON is now located at 203 Atco Bldg., Tulsa, Okla.

MR. C. W. PURDY has returned from South America.

MR. W. M. SMALL has returned from Mexico for a visit.

MR. E. EGGLESTON SMITH is in the United States on a visit.

RESEARCH SERVICE, 100 Lexington Ave., New York City, has been organized for bibliographic service, translation of articles in foreign languages, and all kinds of research. Orders are taken for foreign and domestic maps and geological publication.

MR. RALPH ARNOLD is President and MR. CHARLES WAGNER, Secretary of the Branner Club of Southern California which meets in Los Angeles every three weeks.

MR. J. P. D. HULL is Chairman and MR. J. O. NELSON Secretary of the Shreveport Section of the Southwestern Geological Society.

MR. ROBERT J. RIGGS made the location for the well of Campbell, et al. in Sec. 8, T. 13 N., R. 15 E., Okmulgee Co., Oklahoma.

MR. C. A. WARNER represents the Houston Oil Co. at Okmulgee, Okla.

MR. L. J. YOUNGS has resigned from the Oklahoma Producing & Refining Corporation and is now with the Gypsy Oil Co., at Tulsa, Okla.

MR. V. O. TANSEY is with the Gypsy Oil Co., at Tulsa, Oklahoma.

MR. HERBERT SHELTON is Chief Geologist for the Buckley Interests in Mexico, working under the direction of Mr. Ben C. Belt.

MR. W. F. BOWMAN is with the Rio Bravo Oil Co., at Houston, Texas.

MR. O. E. HANS is with the Phillips Petroleum Co., at Bartlesville, Okla.

MR. T. C. LINDERFELT is Chief Geologist for the Rood Oil Corporation of Bartlesville, Okla.

MR. A. O. DOVRE is Chief Geologist for the Venezuelan Sun Co., Ltd., with headquarters at Maracaibo, Venezuela.

THE THIRTEENTH SESSION OF THE INTERNATIONAL GEOLOGICAL CONGRESS will be held at Bruxelles, Belgium, August 10th to 19th, 1922. The first excursions, commencing August 1st will illustrate the geology of Belgium. The second excursions are for one day only and are held during the session. Additional excursions with a maximum duration of 12 days follow the meeting. Professor A. Renier, of the University of Liege, Bruxelles, is the Secretary General.

THE WICHITA GEOLOGICAL CLUB has recently been organized at Wichita, Kansas, membership in which is limited to those who are eligible to membership in the American Association of Petroleum Geologists. There is at present possibility of some 35 to 40 members in and around Wichita. The officers of the Club for the present year are ROY S. HAZELTON, *President*, HERMAN J. ALLEN AND WILLIAM AINSWORTH, *Vice-Presidents*, AND A. I. LEVORSEN, *Secretary-Treasurer*. Meetings are held at least once a month and it is the plan of the Club to make them as informal as possible.

MR. DONALD MCARTHUR is engaged in foreign exploration work for the Tropical Oil Company, with present address as Cartagena, Colombia.

MR. FRANK B. NOTESTEIN is engaged in exploration work in Egypt.

MR. THERON WASSON AND MR. JOSEPH H. SINCLAIR recently returned to the United States from Ecuador. Mr. Wasson has been made Chief Geologist of the Pure Oil Company, with headquarters at Tulsa, Okla. Mr. Sinclair will be associated with Mr. E. B. Hopkins at 25 Broadway, New York City.

MR. HARRY J. BROWN, Chief Geologist of the Pierce Oil Corporation, is now located in the Wagonner Building at Fort Worth, Texas.

MR. E. E. LINDEBLAD has returned to the Empire Gas & Fuel Company and will work in Kansas.

MR. J. W. MERRITT is Chief Geologist for the Freeborn Engineering Company of Tulsa, Oklahoma.

MR. L. B. BENTON, of the Humble Oil & Refining Company, has returned from Houston to Ardmore, Oklahoma.

MR. MAX A. PISCHEL is Consulting Geologist for the Mid-Co. Pet. Company in Tulsa and has his office at 1046 Kennedy Bldg.

MR. E. W. HUMMEL has been in South America.

The firm of EATON AND LOOMIS has been dissolved. Mr. Harve Loomis will continue his practice as Consulting Geologist at 812 American National Bank Building, Oklahoma City, Okla.

MR. F. G. CLAPP, of New York City, recently made a trip through the Mid-Continent fields.

MR. FRANK EDSON has returned from Mexico and is at Norman, Okla.

MR. MAX W. BALL, of Denver, Colorado, is President of the newly formed Rocky Mountain Geological Society.

MR. MYRON L. FULLER is on a pleasure trip in Europe

MR. E. L. ESTABROOK published a paper entitled: "Production problems in the Grass Creek oil field," in the February number of Mining and Metallurgy.

MR. GEORGE C. MATSON, General Manager of the Schermerhorn Oil Co., has his office at 408 Cosden Bldg., Tulsa, Okla.

THE SHREVEPORT SECTION OF THE SOUTHWESTERN GEOLOGICAL SOCIETY is backing a movement to reestablish a geological survey in Louisiana with the Professor of Geology at the State University as Director. At the present time there is no geological department at the University. The committee which is drafting a bill for the legislature consists of Clyde M. Bennett, John Y. Snyder, and Ben K. Stroud.

MR. MORRIS E. MORTIMER is in South America for The Texas Co.

SUPPORT YOUR ADVERTISERS

We have arranged for a good amount of advertising for the next issue. We hope that the members will justify our representations and encourage further support of our publication, first, by endeavoring to secure your requirements from those who advertise in this Bulletin, and second, by calling the advertiser's attention to that fact whenever an order is placed.

A small amount of attention to these two points on the part of each of you will result in a large amount of benefit to your Association, to your Bulletin, and to yourself. Will you help us in this?

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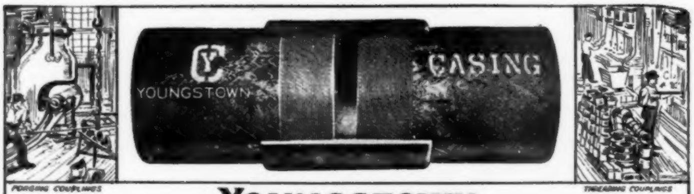

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